New papers about near-infrared spectroscopy (NIRS) and imaging (NIRI)

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Number of papers included: **86**

Note: The highlighted parts of the abstracts refer to the most important findings.

1. Kinoshita et al. (2015). **Effect of metabotropic glutamate receptor-3 variants on prefrontal brain activity in schizophrenia: An imaging genetics study using multi-channel near-infrared spectroscopy**

Abstract: Background: The glutamatergic system is essential for learning and memory through its crucial role in neural development and synaptic plasticity. Genes associated with the glutamatergic system, including metabotropic glutamate receptor (mGluR or GRM) genes, have been implicated in the pathophysiology of schizophrenia. Few studies, however, have investigated a relationship between polymorphism of glutamate-related genes and cortical function in vivo in patients with schizophrenia. We thus explored an association between genetic variations in GRM3 and brain activation driven by a cognitive task in the prefrontal cortex in patients with schizophrenia.
Materials and Methods: Thirty-one outpatients with schizophrenia and 48 healthy controls participated in this study. We measured four candidate single nucleotide polymorphisms (rs274622, rs2299225, rs1468412, and rs6465084) of GRM3, and activity in the prefrontal and temporal cortices during a category version of a verbal fluency task, using a 52-channel near-infrared spectroscopy instrument.
Results and Discussion: The rs274622 C carriers with schizophrenia were associated with significantly smaller prefrontal activation than patients with TT genotype. This between-genotype difference tended to be confined to the patient group. GRM3 polymorphisms are associated with prefrontal activation during cognitive task in schizophrenia.

2. Wightman et al. (2015). **Dietary nitrate modulates cerebral blood flow parameters and cognitive performance in humans: A double-blind, placebo-controlled, crossover investigation**

Abstract: Nitrate derived from vegetables is consumed as part of a normal diet and is reduced endogenously via nitrite to nitric oxide. It has been shown to improve endothelial function, reduce blood pressure and the oxygen cost of sub-maximal exercise, and increase regional perfusion in the brain. The current study assessed the effects of dietary nitrate on cognitive performance and prefrontal cortex cerebral blood-flow (CBF) parameters in healthy adults. In this randomised, double-blind, placebo-controlled, parallel-groups study, 40 healthy adults received either placebo or 450 ml beetroot juice (~ 5.5 mmol nitrate). Following a 90 minute drink/absorption period, participants performed a selection of cognitive tasks that activate the frontal cortex for 54 min. Near-Infrared Spectroscopy (NIRS) was used to monitor CBF and hemodynamics, as indexed by concentration changes in oxygenated and deoxygenated-haemoglobin, in the frontal cortex throughout. The bioconversion of nitrate to nitrite was confirmed in plasma by ozone-based chemi-luminescence. Dietary nitrate modulated the hemodynamic response to task performance, with an initial increase in CBF at the start of the task period, followed by consistent reductions during the least demanding of the three tasks utilised. Cognitive performance was improved on the serial 3s subtraction task. These results show that single doses of dietary nitrate can modulate the CBF response to task performance and potentially improve cognitive performance, and suggest one possible mechanism by which vegetable consumption may have beneficial effects on brain function.

3. Leon-Dominquez et al. (2015). **Executive *n*-back tasks for the neuropsychological assessment of working memory**

Abstract: Working memory (WM) has been defined as a cerebral function which allows us to maintain and manipulate information "online". One of the most widely used paradigms to assess WM is the n-back test. Despite its extensive application, some authors have questioned its capacity to assess the manipulation of WM load. The present study introduces a new version of the n-back test to carry out this assessment. We use functional near-infrared spectroscopy (fNIRS) to evaluate prefrontal cortex (PFC) activation. The modified n-back requires monitoring of sequentially presented stimuli (in this case the days of the week). The target response relates to a stimulus which appears previously, from 0 to 2 items back, on the computer screen. Our data reveals that while modified and unmodified n-back activate the same regions of the left PFC, our modified 2-back version shows significantly higher activation in the left dorsolateral PFC (DLPFC) and the left frontal opercula. These results suggest that increased complexity in verbal WM tasks entail greater executive control, which would lead to an increase in cerebral blood flow to the areas associated with verbal WM. Therefore, an increase in the manipulation of WM load in verbal tasks reflects greater physiological activity in the left DLPFC and the left frontal opercula. The modified n-back test may also be incorporated into the armamentarium of valid instruments for the neuropsychological assessment of the maintenance and manipulation of verbal information in tasks requiring working memory.

4. Leon-Dominquez et al. (2015). **Low intensity exercise does not impact cognitive function during exposure to normobaric hypoxia**

Abstract: Exposure to hypoxia is associated with cognitive impairment, mediated by cerebral deoxygenation. This can be problematic for individuals who perform mental tasks at high altitude. Eight healthy men completed two experimental trials consisting of 5 h of exposure to normobaric hypoxia (12.5% O2). In one of the experimental trials (Hypoxia) subjects remained resting in a seated position the entire 5 h; in the other experimental trial (Hypoxia and Exercise) subjects rested 2 h, cycled for 1 h at constant wattage (workload equivalent to 50% of altitude adjusted VO2max), then rested the last 2 h. Cerebral oxygenation was measured continuously via near-infrared spectroscopy and cognitive performance was assessed by Trail Making Test A and B. Cerebral oxygenation and cognitive performance both were impaired during exposure to hypoxia. In the Hypoxia and Exercise trial, subjects experienced further declinations in cerebral oxygenation without concomitant decreases in cognitive function. These data demonstrate that cognitive function declines during exposure to normobaric hypoxia and this decline is not exacerbated by low intensity exercise.

5. Leon-Dominquez et al. (2015). **Exploring methodological frameworks for a mental task-based near-infrared spectroscopy brain–computer interface**

Abstract: Background: Near-infrared spectroscopy (NIRS) brain–computer interfaces (BCIs) enable users to interact with their environment using only cognitive activities. This paper presents the results of a comparison of four methodological frameworks used to select a pair of tasks to control a binary NIRS-BCI; specifically, three novel personalized task paradigms and the state-of-the-art prescribed task framework were explored.
New methods: Three types of personalized task selection approaches were compared, including: user-selected mental tasks using weighted slope scores (WS-scores), user-selected mental tasks using pair-wise accuracy rankings (PWAR), and researcher-selected mental tasks using PWAR. These paradigms, along with the state-of-the-art prescribed mental task framework, where mental tasks are selected based on the most commonly used tasks in literature, were tested by ten able-bodied participants who took part in five NIRS-BCI sessions.
Results: The frameworks were compared in terms of their accuracy, perceived ease-of-use, computational time, user preference, and length of training. Most notably, researcher-selected personalized tasks resulted in significantly higher accuracies, while user-selected personalized tasks resulted in significantly higher perceived

ease-of-use. It was also concluded that PWAR minimized the amount of data that needed to be collected; while, WS-scores maximized user satisfaction and minimized computational time.
Comparison with existing method: In comparison to the state-of-the-art prescribed mental tasks, our findings show that overall, personalized tasks appear to be superior to prescribed tasks with respect to accuracy and perceived ease-of-use.
Conclusions: The deployment of personalized rather than prescribed mental tasks ought to be considered and further investigated in future NIRS-BCI studies.

6. Abramo et al. (2015). **Cerebral oximetry with cerebral blood volume index in detecting pediatric stroke in a pediatric ED**

Abstract: Background: Despite pediatric stroke awareness and pediatric stroke activation systems, recognition and imaging delays along with activation inconsistency still occur. Reliable objective pediatric stroke detection tools are needed to improve detection and activations. Regional cerebral oxygen saturation (rcso2) with cerebral blood volume index (CBVI) can detect abnormal cerebral physiology.
Objective: To determine cerebral oximetry in detecting strokes in stroke alert and overall stroke patients.
Method: Left rcso2, right rcso2, and rcso2 side differences for stroke, location, and types were analyzed.
Results: Compared with stroke alert (n = 25) and overall strokes (n = 52), rcso2 and CBVI were less than those in nonstrokes (n = 133; P < .0001). Rcso2 side differences in stroke alert and overall strokes were greater than in nonstrokes (P < .0001). Lower rcso2 and CBVI correlated with both groups' stroke location, left (P < .0001) and right rcso2 (P = .004). Rcso2 differences greater than 10 had a 100% positive predictive value for stroke. Both groups' rcso2 and CBVI side differences were consistent for stroke location and type (P < .0001). For both groups, left rcso2 and CBVI were greater than those of the right (P < .0001). Hemorrhagic strokes had lower bilateral rcso2 and CBVI than did ischemic strokes (P < .001).
Conclusions: Cerebral oximetry and CBVI detected abnormal cerebral physiology, stroke location, and type (hemorrhagic or ischemic). Rcso2 side differences greater than 10 or rcso2 readings less than 50% had a 100% positive predictive value for stroke. Cerebral oximetry has shown potential as a detection tool for stroke location and type in a pediatric stroke alert and nonalert stroke patients. Using cerebral oximetry by the nonneurologist, we found that the patient's rcso2 side difference greater than 10 or one or both sides having less than 50% rcso2 readings suggests abnormal hemispheric pathology and expedites the patient's diagnosis, neuroresuscitation, and radiologic imaging.

7. Liu et al. (2015). **Role of the right inferior frontal gyrus in turn-based cooperation and competition: A near-infrared spectroscopy study**

Abstract: Interpersonal interaction can be classified into two types: concurrent and turn-based interaction, requiring synchronized body-movement and complementary behaviors across persons, respectively. To examine the neural mechanism of turn-based interaction, we simultaneously measured paired participants activations in their bilateral inferior frontal gyrus (IFG) and the bilateral inferior parietal lobule (IPL) in a turn-taking game using near-infrared spectroscopy (NIRS). Pairs of participants were assigned to either one of two roles (game builder and the partner) in the game. The builder's task was to make a copy of a target disk-pattern by placing disks on a monitor, while the partner's task was to aid the builder in his/her goal (cooperation condition) or to obstruct it (competition condition). The builder always took the initial move and the partner followed. The NIRS data demonstrated an interaction of role (builder vs. partner) by task-type (cooperation vs. competition) in the right IFG. The builder in the cooperation condition showed higher activation than the cooperator, but the same builder in the competition condition showed lower activation than in the cooperation condition. The activations in the competitor–builder pairs showed positive correlation between their right IFG, but the activations in the cooperator–builder pairs did not. These results suggest that the builder's activation in the right IFG is reduced/increased in the context of interacting with a cooperative/competitive partner. Also, the competitor may actively trace the builder's disk manipulation, leading to deeper mind-set synchronization in the competition

condition, while the cooperator may passively follow the builder's move, leading to shallower mind-set synchronization in the cooperation condition.

8. Gayda et al. (2015). **Cerebral Hemodynamics During Exercise and Recovery in Heart Transplant Recipients**

Abstract: Background: The aims of this work were (1) to compare cerebral oxygenation-perfusion (COP), central hemodynamics, and peak oxygen uptake (View the MathML sourceV˙o2peak) in heart transplant recipients (HTRs) vs age-matched healthy controls (AMHCs) during exercise and recovery and (2) to study the relationships between COP, central hemodynamics, and View the MathML sourceV˙o2peak in HTRs and AMHCs.
Methods: Twenty-six HTRs (3 women) and 27 AMHCs (5 women) were recruited. Maximal cardiopulmonary function (gas exchange analysis), cardiac hemodynamics (impedance cardiography), and left frontal COP (near-infrared spectroscopy) were measured continuously during and after a maximal ergocycle (Ergoline 800S, Bitz, Germany) test.
Results: Compared with AMHCs, HTRs had lower View the MathML sourceV˙o2peak, maximal cardiac index (CImax), and maximal ventilatory variables ($P < 0.05$). COP was lower during exercise (oxyhemoglobin [ΔO2Hb], 50% and 75% of View the MathML sourceV˙O2peak, total hemoglobin [ΔtHb], 100% of View the MathML sourceV˙O2peak; $P < 0.05$), and recovery in HTRs (ΔO2Hb, minutes 2-5; ΔtHb, minutes 1-5; $P < 0.05$) compared with AMHCs. End-tidal pressure of CO2 was lower during exercise compared with that in AMHCs ($P < 0.0001$). In HTRs, CImax was positively correlated with exercise cerebral hemodynamics ($R = 0.54\text{-}0.60$; $P < 0.01$).
Conclusions: In HTRs, COP was reduced during exercise and recovery compared with that in AMHCs, potentially because of a combination of blunted cerebral vasodilation by CO2, cerebrovascular dysfunction, reduced cardiac function, and medication. The impaired View the MathML sourceV˙O2peak observed in HTRs was mainly caused by reduced maximal ventilation and CI. In HTRs, COP is impaired and is correlated with cardiac function, potentially impacting cognitive function. Therefore, we need to study which interventions (eg, exercise training) are most effective for improving or normalizing (or both) COP during and after exercise in HTRs.

9. Grant et al. (2015). **Reliability and reactivity of the prefrontal hemodynamic responses in essential hypertension: a functional near infrared spectroscopy study**

Abstract: Prefrontal (PFC) cerebral vasoreactivity may be altered in hypertension but has not been studied during postural change and carbon dioxide (CO2) rebreathing. In this study, a dual procedure of 5% CO2 rebreathing with positional change (standing to supine and reverse) was performed on normotensive ($N = 24$) and essential hypertensive males ($N = 16$) (18–55 years) to assess reliability of PFC responses using functional near infrared spectroscopy. The groups (matched on age levels, $N = 13$) were also compared on their hemodynamic reactivity (change of oxyhemoglobin or total hemoglobin as a function of change in end tidal CO2). Test–retest reliability within one session and 7 days later was moderate to high (intraclass correlation coefficient = .63–.901) in both normotensive and hypertensive groups for all hemodynamic measures; whereas reliability of reactivity measures for oxyhemoglobin and total hemoglobin was moderate (intraclass correlation coefficient = .68–.762). Functional near infrared spectroscopy–measured PFC hemodynamic responses are highly reproducible in normotensive and adult essential hypertensive males.

10. Tauchen et al. (2015). **The Effect of Compression Stockings on Cerebral Desaturation Events in Obese Patients Undergoing Shoulder Arthroscopy in the Beach-Chair Position**

Abstract: Purpose: To determine if the use of thigh-high compression stockings could decrease the incidence of cerebral desaturation events (CDEs) in patients with a body mass index (BMI) of 30 kg/m2 or greater undergoing shoulder arthroscopy in the beach-chair position (BCP).
Methods: Between December 2013 and May 2014, 23 patients aged 18 years or older with a BMI of 30 kg/m2 or greater undergoing shoulder arthroscopy in the BCP were monitored intraoperatively using near-infrared spectroscopy while wearing thigh-high compression stockings. Data obtained on these patients were compared with data from a previous cohort at our institution comprising 24 patients with a BMI of 30 kg/m2 or greater who underwent elective shoulder arthroscopy in the BCP with the same monitoring but without wearing compression stockings. The incidence of CDEs was identified in each group.
Results: The incidence of CDEs in the group with compression stockings was 4% (1 of 23) compared with 18% (7 of 24) in the group without compression stockings (P = .048). There were no statistically significant differences in mean age (53.0 years v 53.3 years, P = .91), mean BMI (34.5 kg/m2v 36.2 kg/m2, P = .21), or various medical comorbidities between the treatment group and control group. There was a significant difference in the operative time between the treatment group (156.6 minutes) and control group (94.1 minutes) (P < .001).
Conclusions: The use of thigh-high compression stockings may decrease the incidence of CDEs in obese patients undergoing shoulder arthroscopy in the BCP.

11. Cortés et al. (2015). **Near infrared spectroscopy (NIRS) to assess the effects of local ischemic preconditioning in the muscle of healthy volunteers and critically ill patients**

Abstract: Near-infrared spectroscopy (NIRS) permits non-invasive evaluation of tissue oxygen saturation (StO2). A vascular occlusion test (VOT) produces transient controlled ischemia similar to that used in ischemic preconditioning. We hypothesized that we could evaluate local responses to ischemic preconditioning by performing repeated VOTs and observing the changes in different NIRS VOT-derived variables. In healthy volunteers (n = 20), four VOTs were performed at 30-min intervals on one day and, in a second group (n = 21), two VOTs with time intervals of 5, 15 or 30 min were performed on 3 separate days. Two cohorts of patients, one with circulatory shock (n = 23) and a hemodynamically stable group (n = 20), were also studied, repeating the VOT twice with a 5-min interval. In the 1-day volunteers, there was a median decrease of 15 (6–21)% in the Desc slope (StO2 decrease during VOT) after the second VOT, but no significant change in the Asc slope (StO2 increase after VOT). In the 3-day volunteers, the Desc slope also decreased, regardless of the time interval between VOTs. There was no overall decrease in the Desc slope in either patient cohort with repeated VOTs but there was marked individual patient variability. Patients in whom the Desc slope decreased had less organ dysfunction at admission, required less norepinephrine (0.00 vs 0.08 mcg/kg/min, p = 0.02), less frequently had sepsis (12 vs 50%, p = 0.02) and had a lower mortality (6 vs 39%, p = 0.03) compared to those in whom it did not decrease. Repeated NIRS VOT can non-invasively assess the local effects of ischemic preconditioning in the muscle.

12. Holper et al. (2015). **Brain correlates of verbal fluency in subthreshold psychosis assessed by functional near-infrared spectroscopy**

Abstract: The prevalence of subthreshold psychotic symptoms in the general population has gained increasing interest as a possible precursor of psychotic disorders. The goal of the present study was to evaluate whether neurobiological features of subthreshold psychotic symptoms can be detected using verbal fluency tasks and functional near-infrared spectroscopy (fNIRS).
A large data set was obtained from the Zurich Program for Sustainable Development of Mental Health Services (ZInEP). Based on the SCL-90-R subscales 'Paranoid Ideation' and 'Psychoticism' a total sample of 188 subjects

was assigned to four groups with different levels of subthreshold psychotic symptoms. All subjects completed a phonemic and semantic verbal fluency task while fNIRS was recorded over the prefrontal and temporal cortices. Results revealed larger hemodynamic (oxy-hemoglobin) responses to the phonemic and semantic conditions compared to the control condition over prefrontal and temporal cortices. Subjects with high subthreshold psychotic symptoms exhibited significantly reduced hemodynamic responses in both conditions compared to the control group. Further, connectivity between prefrontal and temporal cortices revealed significantly weaker patterns in subjects with high subthreshold psychotic symptoms compared to the control group, possibly indicating less incisive network connections associated with subthreshold psychotic symptoms.
The present findings provide evidence that subthreshold forms of psychotic symptoms are associated with reduced hemodynamic responses and connectivity in prefrontal and temporal cortices during verbal fluency that can be identified using fNIRS.

13. Jang et al. (2015). **Solid hemoglobin-polymer phantoms for evaluation of biophotonic systems**

Abstract: Stable tissue phantoms that incorporate the spectral absorption properties of hemoglobin would benefit a wide range of biophotonic technologies. Toward this end, we have developed and validated a novel polymer material incorporating hemoglobin. Our solid hemoglobin-polymer (SHP) material is fabricated by mixing liquid silicone base with a hemoglobin solution, followed by sonication and low temperature curing. The optical properties of samples were determined over 450–1000 nm using the inverse adding-doubling method and the Beer–Lambert law. Measurements indicated SHP optical stability over four months. Near-infrared spectroscopy and hyperspectral imaging measurements of SHP samples were performed to demonstrate the utility of this approach. SHP materials have the potential to improve tissue-simulating phantoms used for development, evaluation, and standardization of optical devices for oximetry and other applications.

14. Morishita et al. (2015). **Pain reduction associated with improved functional interhemispheric balance following transcranial direct current stimulation for post-stroke central pain: A case study**

Abstract: not available

15. Baik et al. (2015). **Reference Ranges for Cerebral Tissue Oxygen Saturation Index in Term Neonates during Immediate Neonatal Transition after Birth**

Abstract: Background: Non-invasive monitoring of the brain with near-infrared spectroscopy (NIRS) during immediate transition after birth is of growing interest. Objective: The aim of this work was to define reference ranges and centile charts for a regional cerebral tissue oxygenation index (cTOI), measured with the NIRO 200NX (NIRO, Hamamatsu, Japan), and cerebral fractional tissue oxygen extraction (cFTOE) during the first 15 min after birth in preterm and term neonates without any medical support. Methods: cTOI was measured with the NIRO 200NX during the first 15 min after delivery via Caesarean section in preterm and term infants. The NIRS-sensor was placed on the right forehead. Peripheral arterial oxygen saturation (SpO2) and heart rate were continuously measured by pulse oximetry. cFTOE was calculated out of cTOI and SpO2. Neonates with a requirement for any medical support were excluded. Results: A total of 230 neonates were enrolled, from which 90 had to be excluded. Therefore, 140 term neonates were included and data were used to define reference ranges and centile charts. The 50th centile (10th to 90th centiles) of cTOI was 56% (39-75) at 2 min, 66% (50-78) at 5 min, 75% (62-85) at 10 min and 73% (61-84) at 15 min after birth. The 50th centile of cFTOE was 0.24 (0.11-0.44) at 2 min, 0.20 (0.10-0.35) at 5 min, 0.21 (0.09-0.35) at 10 min and 0.24 (0.13-0.37) at 15 min after birth. Conclusion: The present observational study adds the reference ranges and centile charts of cTOI measured with the NIRO 200NX and cFTOE calculated out of cTOI and SpO2 in neonates during the immediate neonatal transition. Centiles for each instrument will be necessary for future clinical application, since the differences

between cTOI and cerebral regional tissue oxygen saturation measured with INVOS 5100C change with increasing regional oxygenation.

16. Roberts et al. (2015). **Cortical oxygenation suggests increased effort during cognitive inhibition in ecstasy polydrug users**

Abstract: Background: It is understood that 3,4-methylenedioxymethamphetamine (ecstasy) causes serotonin dysfunction and deficits in executive functioning. When investigating executive function, functional neuroimaging allows the physiological changes underlying these deficits to be investigated. The present study investigated behavioural and brain indices of inhibition in ecstasy-polydrug users.
Methods: Twenty ecstasy-polydrug users and 20 drug-naïve participants completed an inhibitory control task (Random Letter Generation (RLG)) while prefrontal haemodynamic response was assessed using functional near infrared spectroscopy (fNIRS).
Results: There were no group differences on background measures including sleep quality and mood state. There were also no behavioural differences between the two groups. However, ecstasy-polydrug users displayed significant increases in oxygenated haemoglobin (oxy-Hb) from baseline compared to controls at several voxels relating to areas of the inferior right medial prefrontal cortex, as well the right and left dorsolateral prefrontal cortex. Regression analysis revealed that recency of ecstasy use was a significant predictor of oxy-Hb increase at two voxels over the right hemisphere after controlling for alcohol and cannabis use indices.
Conclusion: Ecstasy-polydrug users show increased neuronal activation in the prefrontal cortex compared to non-users. This is taken to be compensatory activation/recruitment of additional resources to attain similar performance levels on the task, which may be reversible with prolonged abstinence.

17. Wightman et al. (2015). **The effects of chronic *trans*-resveratrol supplementation on aspects of cognitive function, mood, sleep, health and cerebral blood flow in healthy, young humans**

Abstract: Single doses of resveratrol have previously been shown to increase cerebral blood flow (CBF) with no clear effect on cognitive function or mood in healthy adults. Chronic resveratrol consumption may increase the poor bioavailability of resveratrol or otherwise potentiate its psychological effects. In this randomised, double-blind, placebo-controlled, parallel-groups study, a total of sixty adults aged between 18 and 30 years received either placebo or resveratrol for 28 d. On the 1st and 28th day of treatment, the performance of cognitively demanding tasks (serial subtractions, rapid visual information processing and 3-Back) (n 41 complete data sets) was assessed, alongside blood pressure (n 26) and acute (near-IR spectroscopy (NIRS)) and chronic (transcranial Doppler) measures of CBF (n 46). Subjective mood, sleep quality and health questionnaires were completed at weekly intervals (n 53/54). The results showed that the cognitive effects of resveratrol on day 1 were restricted to more accurate but slower serial subtraction task performance. The only cognitive finding on day 28 was a beneficial effect of resveratrol on the accuracy of the 3-Back task before treatment consumption. Subjective ratings of 'fatigue' were significantly lower across the entire 28 d in the resveratrol condition. Resveratrol also resulted in modulation of CBF parameters on day 1, as assessed by NIRS, and significantly increased diastolic blood pressure on day 28. Levels of resveratrol metabolites were significantly higher both before and after the day's treatment on day 28, in comparison with day 1. These results confirm the acute CBF effects of resveratrol and the lack of interpretable cognitive effects.

18. Carlile et al. (2015). **Evaluation of StO_2 tissue perfusion monitoring as a tool to predict the need for lifesaving interventions in trauma patients**

Abstract: Background: Hemorrhage remains the leading cause of mortality in preventable trauma deaths. Earlier recognition of hemorrhagic shock decreases the time to implementation of life-saving interventions improves patient survival. The presence of hemorrhagic shock is not always apparent using standard vital signs monitoring, a clinical state referred to as occult shock.

Methods: This prospective, observational study was performed at Memorial Hermann Hospital in Houston, TX. Prisoners, pregnant women, and patients with burn injuries greater than 20% total body surface area or bilateral upper extremity fractures were excluded. Hutchinson Technologies Spot Check StO2 device was used to measure StO2 values.
Results: StO2 values less than 75% were predictive of the need for blood product transfusions (P < .01) and the need for emergency surgeries. Nearly one-third of patients who presented with a systolic blood pressure 120 mm Hg or more presented with StO2 less than 75% and had a median base deficit of 5 (3 to 6.5).
Conclusions: Admission StO2 measurements less than 75% predict the need for blood products and emergent surgical procedures and may be used as an adjunct method for identifying shock. StO2 measurements can aid where laboratory values are unavailable.

19. Hilly et al. (2015). **Use of near-infrared spectroscopy in predicting response to intravenous fluid load in anaesthetized infants**

Abstract: Introduction: The prediction of fluid responsiveness in paediatrics and infants remains problematic. We sought to test the validity of the measurement of StcO2 as a predictive parameter of fluid responsiveness in infants less than one year old during non-cardiac surgery.
Materials and methods: This was a prospective observational study on infants aged less than 1 year without any cardiac disease during the intraoperative period of non-cardiac surgery. Cerebral oxygen saturation (StcO2) was obtained using infrared spectroscopic INVOS® monitors. Reference values were obtained 10 minutes after intubation. Fluid load indications were dependent on the anaesthesiologist caring for the patient. The objective of this study was to determine the accuracy of StcO2 values before vascular filling (StcO2B) and the difference in StcO2 values between the reference value and before vascular filling (ΔStcO2), in predicting vascular filling response defined as an increase in mean arterial pressure over 15%. Statistical analysis was carried out using ROC curve analysis with determination of grey zones.
Results: Twenty-nine patients were eligible for this study, 23 were included in the study (one intravenous fluid challenge per patient). There were 10 responders and 13 non-responders. The StcO2B and the ΔStcO2 were significantly different between responders and non-responders. Analysis of the ROC curve found an area under the curve of 0.75 [95% CI 0.56 to 0.95] for StcO2B and 0.83 [95% CI 0.66 to 0.99] for ΔStcO2. The grey-areas were [59–78] and [16–28] for StcO2B and ΔStcO2.
Conclusion: NIRS appears to be an interesting additional tool for predicting an increase of blood pressure in response to intraoperative fluid challenge in infants less than one year old.

20. Van der Laan et al. (2015). **The Association between Multisite Near-Infrared Spectroscopy and Routine Hemodynamic Measurements in Relation to Short-Term Outcome in Preterms with Clinical Sepsis**

Abstract: Background: The added clinical value of multisite near-infrared spectroscopy (NIRS) monitoring to detect low organ tissue perfusion in preterm infants at risk of circulatory failure remains unclear. Objectives: To evaluate the associations between multisite NIRS measurements and clinical signs of circulatory failure in relation to short-term outcome in preterm infants with clinical sepsis. Methods: Prospective cohort study of preterm infants (gestational age <32 weeks) with clinical sepsis. We monitored cerebral, renal, and intestinal oxygen saturation using NIRS for 72 h following sepsis workup and calculated fractional tissue oxygen extraction (FTOE). We recorded clinical signs of circulatory failure every 8 h. We analyzed the associations between FTOE values, clinical signs of circulatory failure, and short-term outcome. Results: In 28 preterm infants with clinical sepsis, intraindividual and interindividual associations between NIRS values and clinical signs of circulatory failure were weak. At several points of time during the study period, cerebral and renal FTOE were higher in infants who developed intestinal complications compared with infants who did not, while clinical signs of circulatory failure never differed between groups. After correcting for multiple testing, significant differences disappeared. Conclusions: The associations between multisite FTOE values and clinical

signs of circulatory failure were weak in preterm infants with clinical sepsis. Nevertheless, in contrast to clinical signs of circulatory failure, cerebral and renal FTOE values were associated with adverse short-term intestinal outcome in the uncorrected analyses. Multisite NIRS monitoring might help to detect critically low tissue oxygen delivery leading to adverse intestinal outcome not detected by routine hemodynamic measurements.

21. Kenosi et al. (2015). **Effects of Fractional Inspired Oxygen on Cerebral Oxygenation in Preterm Infants following Delivery**

Abstract: Objectives: To explore regional cerebral oxygen saturations (rcSO2) in preterm neonates initially stabilized with 0.3 fractionated inspired oxygen (FiO2) concentrations. We hypothesized that those infants who received >0.3 FiO2 during stabilization following delivery would have relatively higher rcSO2 postdelivery compared with those stabilized with a lower FiO2.
Study design: A single center prospective observational study of 47 infants born before 32 weeks. Using near infrared spectroscopy, rcSO2 values were recorded immediately after birth. All preterm infants were initially given 0.3 FiO2 and were divided into 2 groups according to subsequent FiO2 requirements of either ≤0.3 or >0.3 FiO2. Using a mixed-effects model, we compared the difference between the groups over time. Also, the area measures below 55% (hypoxia) and above 85% (hyperoxia) were compared between the groups.
Results: The mean (SD) gestation was 29.4 (1.6) weeks and the mean (SD) weight was 1.3 (0.4) kg. Less than one-half of the infants (20/45; 43%) required ≤0.3 FiO2. In the delivery suite, the median (IQR) rcSO2 in the low and high FiO2 groups were 81% (66%-86%) and 72% (62%-86%), respectively. Patients in the high FiO2 group had a larger rcSO2 area below 55% (P = .01). There was a significant difference in rcSO2 between the groups (P < .05), with the low group having higher rcSO2 values initially, but this difference changed over time. In the neonatal intensive care unit (NICU), rcSO2 values were lower by 7.1% (CI 12.13 to 2.06%) P = .008 in the high FiO2 group.
Conclusions: Infants given >0.3 FiO2 had more cerebral hypoxia than infants requiring ≤0.3 FiO2 but no difference in the degree of cerebral hyperoxia, both in the delivery suite and the NICU. This suggests that a more rapid increase in oxygen titration maybe be required initially for preterm infants.

22. Heilbronner et al. (2015). **Caffeine differentially alters cortical hemodynamic activity during working memory: a near infrared spectroscopy study**

Abstract: Background: Caffeine is a widely used stimulant with potentially beneficial effects on cognition as well as vasoconstrictive properties. In functional magnetic imaging research, caffeine has gained attention as a potential enhancer of the blood oxygenation level-dependent (BOLD) response. In order to clarify changes of oxy- and deoxyhemoglobin (HbO and HbR) induced by caffeine during a cognitive task, we investigated a working memory (WM) paradigm (visual 2-back) using near-infrared spectroscopy (NIRS).
Results: Behaviorally, caffeine had no effect on the WM performance but influenced reaction times in the 0-back condition. NIRS data demonstrate caffeine-dependent alterations of the course of the hemodynamic response. The intake of 200 mg caffeine caused a significant decrease of the HbO response between 20 and 40 s after the onset of a 2-back task in the bilateral inferior frontal cortex (IFC). In parallel, the HbR response of the left IFC was significantly increased due to caffeine intake.
Conclusions: In line with previous results, we did not detect an effect of caffeine on most aspects of behavior. Effects of caffeine on brain vasculature were detected as general reduction of HbO. Neuronal effects of caffeine are reflected in an increased concentration of HbR in the left hemisphere when performing a verbal memory task and suggest influences on metabolism.

23. Moerman et al. (2015). **Cerebral oximetry: the standard monitor of the future?**

Abstract: Purpose of review: There is an increasing interest in the application of near-infrared spectroscopy (NIRS) as a monitoring tool in noncardiac surgery. This review summarizes the latest developments and current evidence for the use of NIRS in the noncardiac intraoperative setting.
Recent findings: Unanticipated intraoperative physiological disturbances and a substantial interpatient variability in the limits of cerebral autoregulation, pose our patients at risk for adverse cerebral outcome, if the brain is not monitored specifically. In addition to a means to monitor the brain, NIRS has been shown to allow an estimate of overall organ oxygenation. Preliminary data suggest a relationship between cerebral desaturation and both neurologic and major organ morbidity.
Summary: NIRS offers noninvasive monitoring of cerebral and overall organ oxygenation in a wide range of clinical scenarios. There is an increasing evidence that the optimized cerebral oxygenation is associated with improved outcomes in both neurologic and major organ morbidity in a variety of surgical settings.

24. Braz et al. (2015). **The impact of age on cerebral perfusion, oxygenation and metabolism during exercise in humans**

Abstract: Age is one of the most important risk factors for dementia and stroke. Examination of the cerebral circulatory responses to acute exercise in the elderly may help to pinpoint the mechanisms by which exercise training can reduce the risk of brain diseases, inform the optimization of exercise training programmes and assist with the identification of age-related alterations in cerebral vascular function. During low-to-moderate intensity dynamic exercise, enhanced neuronal activity is accompanied by cerebral perfusion increases of ~10–30%. Beyond ~60–70% maximal oxygen uptake, cerebral metabolism remains elevated but perfusion in the anterior portion of the circulation returns towards baseline, substantively because of a hyperventilation-mediated reduction in the partial pressure of arterial carbon dioxide (inline image) and cerebral vasoconstriction. Cerebral perfusion is lower in older individuals, both at rest and during incremental dynamic exercise. Nevertheless, the increase in the estimated cerebral metabolic rate for oxygen and the arterial–internal jugular venous differences for glucose and lactate are similar in young and older individuals exercising at the same relative exercise intensities. Correction for the age-related reduction in inline image during exercise by the provision of supplementary CO2 is suggested to remove ~50% of the difference in cerebral perfusion between young and older individuals. A multitude of candidates could account for the remaining difference, including cerebral atrophy, and enhanced vasoconstrictor and blunted vasodilatory pathways. In summary, age-related reductions in cerebral perfusion during exercise are partly associated with a lower inline image in exercising older individuals; nevertheless the cerebral extraction of glucose, lactate and oxygen appear to be preserved.

25. Uemuraet al. (2015). **Age-related changes in prefrontal oxygenation during memory encoding and retrieval**

Abstract: Aim: Memory dysfunction is a major component of age-related cognitive decline, and is a marker of cognitive impairment. Emerging evidence suggests that the prefrontal cortex is required for maintenance of memory functions. The purpose of the present study was to elucidate age-related changes in prefrontal oxygenation during memory encoding and retrieval using near-infrared spectroscopy.
Methods: We examined 21 young (mean age 24.3 years), 52 young-old (mean age 69.7 years) and 50 old-old (mean age 79.5 years) participants. The concentration of oxyhemoglobin, which is a reliable biomarker of changes in regional cerebral blood flow, in the right and left prefrontal cortex was measured during encoding and delayed retrieval of a list of 10 target words. The average number of correct answers in the retrieval task was used as a measure of task performance.
Results: During encoding, oxyhemoglobin was significantly and bilaterally lower in young-old and old-old participants compared with young participants. Meanwhile, during retrieval, only old-old participants showed

significantly decreased oxyhemoglobin compared with young and young-old participants. The old-old participants showed fewer correct answers in the retrieval period than the young and young-old participants.
Conclusions: Old-old participants showed reduced prefrontal oxygenation during both encoding and retrieval, and decreased memory performance compared with younger participants. It is necessary for the clinical application of near-infrared spectroscopy to consider the effects of demographic variables on cerebral oxygenation.

26. Graber al. (2015). **Enhanced resting-state dynamics of the hemoglobin signal as a novel biomarker for detection of breast cancer**

Abstract: Purpose: The work presented here demonstrates an application of diffuse optical tomography (DOT) to the problem of breast-cancer diagnosis. The potential for using spatial and temporal variability measures of the hemoglobin signal to identify useful biomarkers was studied.
Methods: DOT imaging data were collected using two instrumentation platforms the authors developed, which were suitable for exploring tissue dynamics while performing a simultaneous bilateral exam. For each component of the hemoglobin signal (e.g., total, oxygenated), the image time series was reduced to eight scalar metrics that were affected by one or more dynamic properties of the breast microvasculature (e.g., average amplitude, amplitude heterogeneity, strength of spatial coordination). Receiver-operator characteristic (ROC) analyses, comparing groups of subjects with breast cancer to various control groups (i.e., all noncancer subjects, only those with diagnosed benign breast pathology, and only those with no known breast pathology), were performed to evaluate the effect of cancer on the magnitudes of the metrics and of their interbreast differences and ratios.
Results: For women with known breast cancer, simultaneous bilateral DOT breast measures reveal a marked increase in the resting-state amplitude of the vasomotor response in the hemoglobin signal for the affected breast, compared to the contralateral, noncancer breast. Reconstructed 3D spatial maps of observed dynamics also show that this behavior extends well beyond the tumor border. In an effort to identify biomarkers that have the potential to support clinical aims, a group of scalar quantities extracted from the time series measures was systematically examined. This analysis showed that many of the quantities obtained by computing paired responses from the bilateral scans (e.g., interbreast differences, ratios) reveal statistically significant differences between the cancer-positive and -negative subject groups, while the corresponding measures derived from individual breast scans do not. ROC analyses yield area-under-curve values in the 77%–87% range, depending on the metric, with sensitivity and specificity values ranging from 66% to 91%. An interesting result is the initially unexpected finding that the hemodynamic-image metrics are only weakly dependent on the tumor burden, implying that the DOT technique employed is sensitive to tumor-induced changes in the vascular dynamics of the surrounding breast tissue as well. Computational modeling studies serve to identify which properties of the vasomotor response (e.g., average amplitude, amplitude heterogeneity, and phase heterogeneity) principally determine the values of the metrics and their codependences. Findings from the modeling studies also serve to clarify the influence of spatial-response heterogeneity and of system-design limitations, and they reveal the impact that a complex dependence of metric values on the modeled behaviors has on the success in distinguishing between cancer-positive and -negative subjects.
Conclusions: The authors identified promising hemoglobin-based biomarkers for breast cancer from measures of the resting-state dynamics of the vascular bed. A notable feature of these biomarkers is that their spatial extent encompasses a large fraction of the breast volume, which is mainly independent of tumor size. Tumor-induced induction of nitric oxide synthesis, a well-established concomitant of many breast cancers, is offered as a plausible biological causal factor for the reported findings.

27. Weyand al. (2015). **Challenges of implementing a personalized mental task near-infrared spectroscopy brain–computer interface for a non-verbal young adult with motor impairments**

Abstract: Purpose: Near-infrared spectroscopy brain–computer interfaces (NIRS-BCIs) have been proposed as potential motor-free communication pathways. This paper documents the challenges of implementing an NIRS-BCI with a non-verbal, severely and congenitally impaired, but cognitively intact young adult. Methods: A 5-session personalized mental task NIRS-BCI training paradigm was invoked, whereby participant-specific mental tasks were selected either by the researcher or by the user, on the basis of prior performance or user preference. Results: Although the personalized mental task selection and training framework had been previously demonstrated with able-bodied participants, the participant was not able to exceed chance-level accuracies. Challenges to the acquisition of BCI control may have included disinclination to BCI training, structural or functional brain atypicalities, heightened emotional arousal and confounding haemodynamic patterns associated with novelty and reward processing. Conclusions: Overall, we stress the necessity for further clinical NIRS-BCI research involving non-verbal individuals with severe motor impairments.

28. Lei al. (2015). **Mapping the Cortical Activation Changes Induced by Transcranial Direct Current Stimulation: A fNIRS-tDCS Study**

Abstract: Transcranial Direct Current Stimulation (tDCS) is a non-invasive cortical stimulation technology. It uses weak direct currents to modulate the cortical activity below the motor threshold. To better understand the effects of tDCS-induced activation during motor performance, primary motor cortex (M1) activation changes were measures by fNIRS before and after applying tDCS on left M1 with a finger tapping task in eight healthy subjects. This study finds that the effect of tDCS depends on the current polarity. Anodal stimulation excites certain cortical regions and cathodal stimulation produces opposite effect. The finding in this research suggests that the combined use of fNIRS and tDCS can be a useful tool to understand the effect of tDCS. tDCS combined fNIRS can provide insights into changes in activity induced by tDCS, which may find future use guidance on motor rehabilitation.

29. Balconi al. (2015). **Past and future of near-infrared spectroscopy in studies of emotion and social neuroscience**

Abstract: Near-infrared spectroscopy (NIRS) enables the non-invasive measurement of spatiotemporal characteristics of brain function, which has received increasing attention during the last years. This new birth of interest is attributable to unique characteristics of the NIRS technique, which may be summarised in certain technical advantages: its experimental and ecological validity and the extension of application to clinical samples. This paper presents the main applications of the NIRS technique that measures changes in brain activation to study emotions and social neuroscience field. In the first part of this paper, we discuss the basic principles, strengths, and limitations of NIRS for the study of principal emotional functions. In the second part, we focus on the actual applications of NIRS in emotional and social research. In this regard, first, we consider some main topics of emotional contexts, such as visual (facial expression) and auditory cues recognition, and social neuroscience field. Second, we discuss the utility to apply NIRS simultaneously to other techniques (electroencephalography, Transcranial Magnetic Stimulation, and functional Magnetic Resonance Imaging) to improve the intrinsic power of such measures. Third, we consider the possible applications of NIRS devices to study specific emotion-related functions (such as connectivity and plasticity applications).

30. Bowman al. (2015). **Children's belief- and desire-reasoning in the temporoparietal junction: evidence for specialization from functional near-infrared spectroscopy**

Abstract: Behaviorally, children's explicit theory of mind (ToM) proceeds in a progression of mental-state understandings: developmentally, children demonstrate accurate explicit desire-reasoning before accurate explicit belief-reasoning. Given its robust and cross-cultural nature, we hypothesize this progression may be paced in part by maturation/specialization of the brain. Neuroimaging research demonstrates that the right temporoparietal junction (TPJ) becomes increasingly selective for ToM reasoning as children age, and as their ToM improves. But this research has narrowly focused on beliefs or on undifferentiated mental-states. A recent ERP study in children included a critical contrast to desire-reasoning, and demonstrated that right posterior potentials differentiated belief-reasoning from desire-reasoning. Taken together, the literature suggests that children's desire-belief progression may be paced by specialization of the right TPJ for belief-reasoning specifically, beyond desire-reasoning. In the present study, we tested this hypothesis directly by examining children's belief- and desire-reasoning using functional near-infrared spectroscopy in conjunction with structural magnetic resonance imaging to pinpoint brain activation in the right TPJ. Results showed greatest activation in the right TPJ for belief-reasoning, beyond desire-reasoning, and beyond non-mental reasoning (control). Findings replicate and critically extend prior ERP results, and provide clear evidence for a specific neural mechanism underlying children's progression from understanding desires to understanding beliefs.

31. Burton al. (2015). **A pilot cohort study of cerebral autoregulation and 2-year neurodevelopmental outcomes in neonates with hypoxic-ischemic encephalopathy who received therapeutic hypothermia**

Abstract: Background: Neurodevelopmental disabilities persist in survivors of neonatal hypoxic-ischemic encephalopathy (HIE) despite treatment with therapeutic hypothermia. Cerebrovascular autoregulation, the mechanism that maintains cerebral perfusion during changes in blood pressure, may influence outcomes. Our objective was to describe the relationship between acute autoregulatory vasoreactivity during treatment and neurodevelopmental outcomes at 2 years of age.
Methods: In a pilot study of 28 neonates with HIE, we measured cerebral autoregulatory vasoreactivity with the hemoglobin volume index (HVx) during therapeutic hypothermia, rewarming, and the first 6 h of normothermia. The HVx, which is derived from near-infrared spectroscopy, was used to identify the individual optimal mean arterial blood pressure (MAPOPT) at which autoregulatory vasoreactivity is greatest. Cognitive and motor neurodevelopmental evaluations were completed in 19 children at 21–32 months of age. MAPOPT, blood pressure in relation to MAPOPT, blood pressure below gestational age + 5 (ga + 5), and regional cerebral oximetry (rSO2) were compared to the neurodevelopmental outcomes.
Results: Nineteen children who had HIE and were treated with therapeutic hypothermia performed in the average range on cognitive and motor evaluations at 21–32 months of age, although the mean performance was lower than that of published normative samples. Children with impairments at the 2-year evaluation had higher MAPOPT values, spent more time with blood pressure below MAPOPT, and had greater blood pressure deviation below MAPOPT during rewarming in the neonatal period than those without impairments. Greater blood pressure deviation above MAPOPT during rewarming was associated with less disability and higher cognitive scores. No association was observed between rSO2 or blood pressure below ga + 5 and neurodevelopmental outcomes.
Conclusion: In this pilot cohort, motor and cognitive impairments at 21–32 months of age were associated with greater blood pressure deviation below MAPOPT during rewarming following therapeutic hypothermia, but not with rSO2 or blood pressure below ga + 5. This suggests that identifying individual neonates' MAPOPT is superior to using hemodynamic goals based on gestational age or rSO2 in the acute management of neonatal HIE.

32. Von Lühmann al. (2015). **Toward a Wireless Open Source Instrument: Functional Near-infrared Spectroscopy in Mobile Neuroergonomics and BCI Applications**

Abstract: Brain-Computer Interfaces (BCIs) and neuroergonomics research have high requirements regarding robustness and mobility. Additionally, fast applicability and customization are desired. Functional Near-Infrared Spectroscopy (fNIRS) is an increasingly established technology with a potential to satisfy these conditions. EEG acquisition technology, currently one of the main modalities used for mobile brain activity assessment, is widely spread and open for access and thus easily customizable. fNIRS technology on the other hand has either to be bought as a predefined commercial solution or developed from scratch using published literature. To help reducing time and effort of future custom designs for research purposes, we present our approach toward an open source multichannel stand-alone fNIRS instrument for mobile NIRS-based neuroimaging, neuroergonomics and BCI/BMI applications. The instrument is low-cost, miniaturized, wireless and modular and openly documented on www.opennirs.org. It provides features such as scalable channel number, configurable regulated light intensities, programmable gain and lock-in amplification. In this paper, the system concept, hardware, software and mechanical implementation of the lightweight stand-alone instrument are presented and the evaluation and verification results of the instrument's hardware and physiological fNIRS functionality are described. Its capability to measure brain activity is demonstrated by qualitative signal assessments and a quantitative mental arithmetic based BCI study with 12 subjects.

33. Aranyi al. (2015). **Anger-based BCI Using fNIRS Neurofeedback**

Abstract: Functional near-infrared spectroscopy (fNIRS) holds increasing potential for Brain-Computer Interfaces (BCI) due to its portability, ease of application, robustness to movement artifacts, and relatively low cost. The use of fNIRS to support the development of affective BCI has received comparatively less attention, despite the role played by the prefrontal cortex in affective control, and the appropriateness of fNIRS to measure prefrontal activity. We present an active, fNIRS-based neurofeedback (NF) interface, which uses differential changes in oxygenation between the left and right sides of the dorsolateral prefrontal cortex to operationalize BCI input. The system is activated by users generating a state of anger, which has been previously linked to increased left prefrontal asymmetry. We have incorporated this NF interface into an experimental platform adapted from a virtual 3D narrative, in which users can express anger at a virtual character perceived as evil, causing the character to disappear progressively. Eleven subjects used the system and were able to successfully perform NF despite minimal training. Extensive analysis confirms that success was associated with the intent to express anger. This has positive implications for the design of affective BCI based on prefrontal asymmetry.

34. Bisconti et al. (2015). **fNIRS brain imaging investigation of phonological awareness and passage comprehension abilities in adult recipients of Cochlear Implants**

Abstract: Purpose The aim of the study was to examine how the brain of individuals with Cochlear Implants (CI) responds to spoken language tasks that underlie successful language acquisition and processing.
Methods During functional Near Infrared Spectroscopy (fNIRS) imaging hearing-impaired CI recipients (n = 10, mean age: 52.7 ± 17.3 years) and normal-hearing controls (n = 10, mean age: 50.6 ± 17.2 years) completed auditory tasks commonly used to investigate neurodevelopmental disorders of language and literacy: (i) phonological awareness and (ii) passage comprehension.
Results The two groups had similar reaction time and performance on experimental tasks, although CI participants had lower accuracy than controls. Overall, both CI recipients and controls exhibited similar patterns of brain activation during the tasks.
Conclusions The results demonstrate that CI recipients show an overall neurotypical pattern of activation during auditory language tasks during which individuals with neurodevelopmental language learning impairments, such as dyslexia, tend to show atypical brain activation. These findings suggest that advancements

in fNIRS neuroimaging with CI recipients may help shed new light on how varying types of difficulties in language processing impact brain organization for language.

35. Wang et al. (2015). **Noninvasive measurement of lower extremity muscle oxygen extraction fraction under cuff compression paradigm**

Abstract: Background: To demonstrate the feasibility of using a susceptibility-based MRI technique with asymmetric spin-echo (ASE) sequence to assess the lower extremity muscle oxygen extraction fraction (OEF) alternations under cuff compression paradigm.
Methods: Approved by the local institutional human study committee, nine healthy young volunteers participated in this study. All the ASE scans were conducted using a 3 Tesla clinical MRI scanner during resting state (pre), 1–3 min (post1) and 3–5 min (post2) after a pressure of 50 mmHg above individual systolic blood pressure imposed on the thigh. Moreover, near-infrared spectroscopy (NIRS) measurements were performed on the same day under the same cuff compression protocol to verify the accuracy of this susceptibility-based method.
Results: In all volunteers, the mean MRI based OEF in gastrocnemius (GAS) muscle increased significantly from 0.28 ± 0.02 (pre) to 0.31 ± 0.03 (post1, $P < 0.05$) and 0.31 ± 0.03 (post2, $P < 0.05$). In addition, mean OEF in soleus (SOL) muscle went up from 0.31 ± 0.01 (pre) to 0.33 ± 0.03 (post1, $P = 0.14$) and 0.37 ± 0.04 (post2, $P < 0.05$). For comparison, NIRS measured 1-%HbO2 (percentage of deoxyhemoglobin concentration within total hemoglobin) in GAS rose significantly from 0.29 ± 0.03 (pre) to 0.31 ± 0.04 (post1, $P < 0.05$) and 0.31 ± 0.04 (post2, $P < 0.05$), which confirmed the accuracy of the MRI-based OEF.
Conclusion: This susceptibility-based OEF quantification technique together with cuff compression paradigm could provide a noninvasive, quantifiable and effective tool for measuring skeletal muscle oxygenation.

36. Kim et al. (2015). **Tissue Oximetry Monitoring in Microsurgical Breast Reconstruction**

Abstract: Traditionally, clinical examination has been the gold standard for flap monitoring in microsurgical breast reconstruction. Capillary refill, color, and handheld Doppler have been used in the postoperative period. However, these methods are subjective; reliant on the assessor's skill and potentially delaying the recognition of flap compromise. More recently, surgeons have used newly developed monitoring technologies to complement their initial clinical evaluation, but the sensitivity and reliability of these devices continue to be evaluated. The ideal monitoring technique should be noninvasive, safe, sensitive, reliable, reproducible, simple to use, and inexpensive. Tissue oximeter monitoring represents an objective means for assessment of real-time flap perfusion and tissue oxygen saturation. Reports in the current literature suggest the use of tissue oximetry has decreased the flap loss rate and improved the flap salvage rate in microsurgical breast reconstruction. In this chapter, tissue oximetry monitoring in microsurgical breast reconstruction is described. In addition, the advantages and disadvantages of other postoperative monitoring techniques are reviewed.

37. Martellani et al. (2015). **The Use of Near Infrared Spectroscopy (NIRS) for Monitoring of Free Flaps**

Abstract: Ever since the introduction of free flaps in reconstructive plastic surgery, the success rates have improved. Nevertheless, postoperative complications leading to flap failure still occur in 6–25 % of cases. As salvage rate depends on the time interval from vascular impairment to surgical reintervention (revision), alternative monitoring devices have been introduced in order to detect flap vascular impairment before their clinical signs become evident. Near infrared spectroscopy (NIRS) has proven to be effective. It is non-invasive, reliable, simple to use, objective, recordable, capable of prolonged continuous monitoring and rapidly responds to circulatory changes. The introduction of this device led to improvement of salvage rates and overall flap survival in our department.

38. Koboyama et al. (2015). **Ipsi- and contralateral frontal cortex oxygenation during handgrip task does not follow decrease on maximal force output**

Abstract: The effect of fatiguing exercise on the ipsi- and contralateral frontal cortex has not been fully clarified. The purpose of this study was to investigate by near-infrared spectroscopy (NIRS) the frontal cortex oxygenation response to a prolonged fatiguing repetitive handgrip exercise performed at maximal voluntary contraction. It was found a significant oxyhemoglobin concentration ([HbO2]) increase ($p < 0.05$), accompanied by a smaller and delayed deoxyhemoglobin concentration ([Hb]) decrease ($p < 0.05$), in both hemispheres. Then, it was indicated higher delayed oxygenation in ipsilateral oxygenation compared to contralateral oxygenation. These results provide further evidence that the complemental interaction between the ipsilateral and contralateral cortex during the fatiguing maximal exercise.

39. Yamada et al. (2015). **Removal of motion artifacts originating from optode fluctuations during functional near-infrared spectroscopy measurements**

Abstract: Functional near-infrared spectroscopy (fNIRS) has been increasingly utilized for detecting human cerebral activity in many disciplines because of the potential for less-restraining conditions. However, users often suffer from motion artifacts originating from optode fluctuation during task execution when the task includes motion. In such cases, the optode fluctuation induces changes both in the reflection by hair and in the transmission between the optode and scalp. If part of the reflected light is directly received by the detector optode (short-circuited light), it will contaminate the fNIRS signal. The transmittance change at the optode–scalp gap will also contaminate the signal. In this study, we proposed an optical model on the influence of optode fluctuation on the fNIRS signal and a method for removing the influence. The model revealed the following: (1) the received short-circuited light and the gap transmittance change generated a baseline change in the detected light intensity, and (2) the signal from the tissues was downscaled with increases in the receiving intensity of short-circuited light. To avoid erroneous detection of short-circuited light, we developed a method that optically eliminated hair-reflected light from the detection using linearly polarized light sources and an orthogonally polarized analyzer. The method was validated with an optical phantom possessing a haired surface. The optical absorbance change of a close source–detector (S-D) pair equipped with polarizers was very similar to that of distant S-D pairs, even though these optodes were artificially fluctuated. By combining the multidistance optode arrangement technique with the short-circuited light elimination method, the measurement could effectively eliminate motion artifacts originating from optode fluctuation.

40. Mehta et al. (2015). **Stunted PFC activity during neuromuscular control under stress with obesity**

Abstract: Objective: Obesity is an established risk factor for impaired cognition, which is primarily regulated by the prefrontal cortex (PFC). However, very little is known about the neural pathways that underlie obesity-related declines in neuromuscular control, particularly under stress. The purpose of this study was to determine the role of the PFC on neuromuscular control during handgrip exertions under stress with obesity.
Methods: Twenty non-obese and obese young adults performed submaximal handgrip exertions in the absence and presence of a concurrent stressful task. Primary dependent measures included oxygenated hemoglobin (HbO2: a measure of PFC activity) and force fluctuations (an indicator of neuromuscular control).
Results: Higher HbO2 levels in the PFC were observed in the non-obese compared to the obese group ($P = 0.009$). In addition, higher HbO2 levels were observed in the stress compared to the control condition in the non-obese group; however, this trend was reversed in the obese group ($P = 0.043$). In general, force fluctuations increased by 26 % in the stress when compared to the control condition ($P = 0.001$) and obesity was associated with 39 %

greater force fluctuation (P = 0.024). Finally, while not significant, obesity-related decrements in force fluctuations were magnified under stress (P = 0.063).
Conclusion: The current study provides the first evidence that neuromuscular decrements with obesity were associated with impaired PFC activity and this relationship was augmented in stress conditions. These findings are important because they provide new information on obesity-specific changes in brain function associated with neuromuscular control since the knowledge previously focused largely on obesity-specific changes in peripheral muscle capacity.

41. Nishimura et al. (2015). **Social Function and Frontopolar Activation during a Cognitive Task in Patients with Bipolar Disorder**

Abstract: Background: It is important to understand the neural basis of functional impairments in patients with bipolar disorder (BD) in order to be able to address the recovery. Recently, neurocognitive impairment emerged as a predictor of psychosocial function. A number of functional brain imaging studies have shown that social function is associated with activation of the prefrontal cortex during a cognitive task in healthy adults, and in patients with major depressive disorder and schizophrenia. However, few studies have been conducted in patients with BD. Methods: We performed multichannel near-infrared spectroscopy (NIRS) imaging to investigate the activation of the prefrontal cortex during a verbal fluency task (VFT). We also used the Social Adaptation Self-Evaluation Scale (SASS) to assess social functioning in patients with BD. Thirty-three depressed patients with BD and 65 age-, gender- and task performance-matched healthy controls (HCs) participated in this study. Results: Depressed patients with BD showed reduced activation in the broader bilateral prefrontal cortex during the VFT compared to HCs. Moreover, a significant positive correlation was observed between the total SASS scores and right prefrontal activation in patients with BD. In the SASS subscores, the interest and motivation factor was also positively correlated with frontopolar activation. Conclusions: These results suggest an association between social function and prefrontal activation in depressed patients with BD. The present study provides evidence that NIRS imaging could be helpful in understanding the neural basis of social function.

42. Milej et al. (2015). **Optimization of the method for assessment of brain perfusion in humans using contrast-enhanced reflectometry: multidistance time-resolved measurements**

Abstract: The aim of the study was to determine optimal measurement conditions for assessment of brain perfusion with the use of optical contrast agent and time-resolved diffuse reflectometry in the near-infrared wavelength range. The source-detector separation at which the distribution of time of flights (DTOF) of photons provided useful information on the inflow of the contrast agent to the intracerebral brain tissue compartments was determined. Series of Monte Carlo simulations was performed in which the inflow and washout of the dye in extra- and intracerebral tissue compartments was modeled and the DTOFs were obtained at different source-detector separations. Furthermore, tests on diffuse phantoms were carried out using a time-resolved setup allowing the measurement of DTOFs at 16 source-detector separations. Finally, the setup was applied in experiments carried out on the heads of adult volunteers during intravenous injection of indocyanine green. Analysis of statistical moments of the measured DTOFs showed that the source-detector separation of 6 cm is recommended for monitoring of inflow of optical contrast to the intracerebral brain tissue compartments with the use of continuous wave reflectometry, whereas the separation of 4 cm is enough when the higher-order moments of DTOFs are available.

43. Boezeman et al. (2015). **The significance of regional hemoglobin oxygen saturation values and limb-to-arm ratios of near-infrared spectroscopy to detect critical limb ischemia**

Abstract: This study examines the application of near-infrared spectroscopy to noninvasively detect critical limb ischemia using regional hemoglobin oxygen saturation in percentage values and regional hemoglobin oxygen saturation limb-to-arm ratios. The regional hemoglobin oxygen saturation values and regional hemoglobin oxygen saturation limb-to-arm ratios were calculated in 61 patients with critical limb ischemia (group A). Measurements were performed in rest at four fixed spots at the most affected lower limb and at a reference spot at both upper arms. Similar measurements were performed in the left lower limb of 30 age-matched control patients without peripheral arterial disease (group B). The regional hemoglobin oxygen saturation values and regional hemoglobin oxygen saturation limb-to-arm ratios were significantly different at all measured spots between the groups (all $p < 0.001$), except for the regional hemoglobin oxygen saturation limb-to-arm ratios of the distal vastus lateralis ($p = 0.056$). However, a broad overlap of individual regional hemoglobin oxygen saturation values and regional hemoglobin oxygen saturation limb-to-arm ratios was found in both groups, which resulted in poor discriminative predictive value of single measurements. Single measurements of regional hemoglobin oxygen saturation values and regional hemoglobin oxygen saturation limb-to-arm ratios at all measured spots have poor discriminative predictive value in detection of critical limb ischemia. Measurement of regional hemoglobin oxygen saturation values and regional hemoglobin oxygen saturation limb-to-arm ratios at any of the measurement spots has no added value in detecting lower limb ischemia in individuals compared with current diagnostic modalities.

44. Ni et al. (2015). **Cerebral oxygen saturation after multiple perioperative influential factors predicts the occurrence of postoperative cognitive dysfunction**

Abstract: Background: Postoperative cognitive dysfunction (POCD) is a frequent complication in elderly patients undergoing major non-cardiac surgery, but its etiology is still unclear. Cerebral oxygen saturation (ScO2) represents the balance of cerebral oxygen supply and demand. The aim of present study was to evaluate the relationship between perioperative ScO2 and POCD, and to verify the hypothesis that the value of ScO2 after multiple perioperative influential factors could predict POCD in elderly patients undergoing total knee arthroplasty (TKA).
Methods: Seventy eight Patients aged more than 65 years undergoing elective TKA with intrathecal anesthesia were enrolled. Cognitive functions were assessed one day before and 6 days after surgery, and POCD were defined according to ISPOCD. Demographics were recorded. Perioperative ScO2, blood pressure (BP), blood gas analysis and other clinical data were monitored and recorded, then the decrease of ScO2, BP and PaO2 after influential factors were calculated.
Results: POCD occurred in 15 patients (19.2 %). BP decreased after anesthesia induction and tourniquet deflation, and PaO2 decreased after cement implantation, then percentage decrease of BP was higher in POCD group. ScO2 of POCD group is significantly lower than non-POCD group ($P < 0.05$), and the absolute value and percentage decrease of ScO2 became significant between two groups after multiple influential factors. ScO2 after all influential factors (anesthesia induction, cement implantation and tourniquet deflation) had the best predictive performance for POCD (AUC = 0.742), and the optimal threshold was 66.5 %.
Conclusions: Perioperative ScO2 of patients with POCD is lower than patients without POCD. ScO2 after multiple perioperative influential factors could be an effective predictor for POCD, which reveal an important role of ScO2 decrease in the development of POCD and provide possible treatment target.

45. Lund et al. (2015). **Ultrasound tagged near infrared spectroscopy does not detect hyperventilation-induced reduction in cerebral blood flow**

Abstract: Introduction: Continuous non-invasive monitoring of cerebral blood flow (CBF) may be important during anaesthesia and several options are available. We evaluated the CerOx monitor that employs ultrasound tagged near infrared spectroscopy to estimate changes in a CBF index (CFI).
Methods: Seven healthy males (age 21–26 years) hyperventilated and were administered phenylephrine to increase mean arterial pressure by 20–30 mmHg. Frontal lobe tissue oxygenation (ScO2) and CFI were obtained using the CerOx and mean blood flow velocity in the middle cerebral artery (MCAvmean) was determined by transcranial Doppler. Blood flow in the internal and external carotid artery (ICAf and ECAf) was determined using duplex ultrasonography and forehead skin blood flow (SkBF) and oxygenation (SskinO2) by laser Doppler and white light spectroscopy.
Results: During hyperventilation MCAvmean and ICAf decreased by 44% (median; interquartile range 40–49; $p = 0.016$) and 46% (40–53; $p = 0.03$), respectively. Conversely, CFI increased by 9% (2–31; $p = 0.016$), while no significant change was observed in ScO2. SkBF increased by 19% (9–53; $p = 0.016$) and SskinO2 by 6% (1–7; $p = 0.047$), although ECAf was unchanged. Administration of phenylephrine was not associated with any changes in MCAvmean, ICAf, ECAf, ScO2, SkBF, SskinO2, or CFI.
Conclusion: The CerOx was able to detect a stable CBF during administration of phenylephrine. However, during hyperventilation MCAvmean and ICAf decreased while CFI increased, likely due to an increase in superficial tissue oxygenation. Thus, CFI does not provide an unbiased evaluation of changes in CBF.

46. Wu et al. (2015). **Fast and efficient image reconstruction for high density diffuse optical imaging of the human brain**

Abstract: Real-time imaging of human brain has become an important technique within neuroimaging. In this study, a fast and efficient sensitivity map generation based on Finite Element Models (FEM) is developed which utilises a reduced sensitivitys matrix taking advantage of sparsity and parallelisation processes. Time and memory efficiency of these processes are evaluated and compared with conventional method showing that for a range of mesh densities from 50000 to 320000 nodes, the required memory is reduced over tenfold and computational time fourfold allowing for near real-time image recovery.

47. Al-Yaha et al. (2015). **Prefrontal Cortex Activation While Walking Under Dual-Task Conditions in Stroke: A Multimodal Imaging Study**

Abstract: Walking while performing another task (eg, talking) is challenging for many stroke survivors, yet its neural basis are not fully understood.To investigate prefrontal cortex activation and its relationship to gait measures while walking under single-task (ST) and dual-task (DT) conditions (ie, walking while simultaneously performing a cognitive task) in stroke survivors.We acquired near-infrared spectroscopy (NIRS) data from the prefrontal cortex during treadmill walking in ST and DT conditions in chronic stroke survivors and healthy controls. We also acquired functional magnetic resonance imaging (fMRI) and NIRS during simulated walking under these conditions.NIRS revealed increased oxygenated hemoglobin concentration in DT-walking compared with ST-walking for both groups. For simulated walking, NIRS showed a significant effect of group and group × task, being greater on both occasions, in stroke survivors. A greater increase in brain activation observed from ST to DT walking/ simulated walking was related to a greater change in motor performance in stroke survivors. fMRI revealed increased activity during DT relative to ST conditions in stroke patients in areas including the inferior temporal gyri, superior frontal gyri and cingulate gyri bilaterally, and the right precentral gyrus. The DT-related increase in fMRI activity correlated with DT-related change in behavior in stroke participants in the bilateral inferior temporal gyrus, left cingulate gyrus, and left frontal pole. Our results provide novel evidence that enhanced brain activity changes relate to dual task motor decrements.

48. Aranyi et al. (2015). **Using fNIRS for Prefrontal-Asymmetry Neurofeedback: Methods and Challenges**

Abstract: Functional near-infrared spectroscopy (fNIRS) has become increasingly accessible in recent years, which allows this relatively lowcost and portable brain sensing modality for the application of braincomputer interfaces (BCI). Although there is a growing body of research on fNIRS-based BCI utilising users' covert psychophysiological activity, there is comparably less research on active BCI, where users engage in thinking strategies with the explicit intention of controlling the behaviour of an interactive system.We draw on four empirical studies, where participants received real-time neurofeedback (NF) of left-asymmetric increase in activation in their dorsolateral prefrontal cortex (DL-PFC), which has previously been identified as a correlate of approach-related motivational tendencies. We discuss methodological considerations and challenges, and provide recommendations about brain-signal selection and integration, NF protocol design, post-hoc and real-time applications of NF success criteria, continuous visual feedback, and individualised feedback based on the variations of the brain-signal in a reference condition.

49. Balconi et al. (2015). **Event-related potentials (ERPs) and hemodynamic (functional near-infrared spectroscopy, fNIRS) as measures of schizophrenia deficits in emotional behavior**

Abstract: Recent research evidences supported the significant role of multimethodological neuroscientific approach for the diagnosis and the rehabilitative intervention in schizophrenia. Indeed both electrophysiological and neuroimaging measures in integration each other appear able to furnish a deep overview of the cognitive and affective behavior in schizophrenia patients (SPs). The aim of the present review is focused on the emotional dysfunctional response taking into account the multimeasures for emotional behavior, i.e., the event-related potentials (ERPs) and the hemodynamic profile functional near-infrared spectroscopy (fNIRS). These measures may be considered as predictive measures of the SPs' deficits in emotional behavior. The integration between ERP and fNIRS may support both the prefrontal cortical localization anomaly and the attentional bias toward some specific emotional conditions (mainly negative).

50. Kovalenko et al. (2015). **Effect of ambient light on near infrared spectroscopy**

Abstract: Background: Concerns have been raised about the ability of Near Infrared Spectroscopy (NIRS) to monitor skeletal tissue regional oxygen saturation (rSO2) in excessive light conditions, as are found under the overhead lights of the operating room. This study seeks to determine whether varying intensities of ambient light exert an influence on NIRS measurements of skeletal tissue rSO2.
Methods: Thirty people were recruited from the staff of a local surgical center to participate in the study. Three separate NIRS devices (Covidien INVOS Cerebral Oximeter 510°C, Nonin EQUANOX Model 7600, and a CASMED MC-2030C Cerebral Oximeter) were used to obtain readings from the anterior compartment of the leg. Illuminance was recorded simultaneously with oximetry data in an operating room with (1) no lights on, (2) room lights, and (3) surgical lamps set to maximal intensity.
Results: No differences were seen in rSO2 values under the different lighting conditions while using the Nonin device. There was a statistically significant difference between rSO2 for lights off versus room lights (-0.933, p=0.0045) as well as for lights off versus operating room (OR) lamps (level 5) (-0.50, p=0.0035) for the INVOS device, although the INVOS device was not always able to produce a reading in the presence of high-intensity OR light. While there was no difference found between lights off and room lights when using the CASMED device, it was unable to display a value in the presence of high-intensity OR lamp light.
Conclusions: The results indicate that the presence of light has an effect on oximetry readings; however, the presence of such an effect is dependent upon the device being used. While other applications of the device, such as cerebral oximetry, may allow for drapes to cover the areas being monitored, monitoring for compartment syndrome of the leg would not be as forgiving. This application would be best served by a device capable of monitoring at all light levels.

51. Osaka et al. (2015). **How Two Brains Make One Synchronized Mind in the Inferior Frontal Cortex: fNIRS-Based Hyperscanning During Cooperative Singing**

Abstract: One form of communication that is common in all cultures is people singing together. Singing together reflects an index of cognitive synchronization and cooperation of human brains. Little is known about the neural synchronization mechanism, however. Here, we examined how two brains make one synchronized behavior using cooperated singing/humming between two people and hyperscanning, a new brain scanning technique. Hyperscanning allowed us to observe dynamic cooperation between interacting participants. We used functional near-infrared spectroscopy (fNIRS) to simultaneously record the brain activity of two people while they cooperatively sang or hummed a song in face-to-face (FtF) or face-to-wall (FtW) conditions. By calculating the inter-brain wavelet transform coherence between two interacting brains, we found a significant increase in the neural synchronization of the left inferior frontal cortex (IFC) for cooperative singing or humming regardless of FtF or FtW compared with singing or humming alone. On the other hand, the right IFC showed an increase in neural synchronization for humming only, possibly due to more dependence on musical processing.

52. Vesoulis et al. (2015). **A Novel Method for Assessing Cerebral Autoregulation in Preterm Infants Using Transfer Function Analysis**

Abstract: Autoregulatory dysfunction is an important contributor to brain injury in premature infants, particularly intraventricular hemorrhage (IVH). The autoregulatory system acts as a filter that dampens the systemic blood flow to follow a normal cerebral perfusion profile.Simultaneous arterial blood pressure and cerebral near infrared spectroscopy (NIRS) data were collected from infants born before 28 weeks estimated gestational age (EGA). The resulting data were preprocessed and then divided into non-overlapping 20-minute epochs. The transfer function estimate was calculated to determine dampening ability.62 infants were prospectively recruited with a mean EGA of 25.4 ± 1.3 weeks and birth weight of 832 ± 199g. 67% were male, 24/62 had IVH, 17/62 received dopamine, 47/62 had antenatal steroid exposure, and 22/62 received fentanyl.Advancing EGA and birth weight z-score predicted stronger dampening while African-American race and IVH of any grade predicted weaker dampening. This preliminary report suggests an impairment in dampening ability associated with immaturity, decreased birth weight z-score and African-American race. Decreased dampening is also associated with IVH, although these results cannot distinguish between decreased dampening as an antecedent or sequela of IVH. These observations should be studied in a larger sample.

53. Torre et al. (2015). **Continuous Metabolic Monitoring in Infant Cardiac Surgery: Toward an Individualized Cardiopulmonary Bypass Strategy**

Abstract: Cardiopulmonary bypass (CPB) in infants is associated with morbidity due to systemic inflammatory response syndrome (SIRS). Strategies to mitigate SIRS include management of perfusion temperature, hemodilution, circuit miniaturization, and biocompatibility. Traditionally, perfusion parameters have been based on body weight. However, intraoperative monitoring of systemic and cerebral metabolic parameters suggest that often, nominal CPB flows may be overestimated. The aim of the study was to assess the safety and efficacy of continuous metabolic monitoring to manage CPB in infants during open-heart repair. Between December 2013 and October 2014, 31 consecutive neonates, infants, and young children undergoing surgery using normothermic CPB were enrolled. There were 18 male and 13 female infants, aged 1.4 ± 1.7 years, with a mean body weight of 7.8 ± 3.8 kg and body surface area of 0.39 m2. The study was divided into two phases: (i) safety assessment; the first 20 patients were managed according to conventional CPB flows (150 mL/min/kg), except for a 20-min test during which CPB was adjusted to the minimum flow to maintain MVO2 >70% and rSO2 >45% (group A); (ii) efficacy assessment; the following 11 patients were exclusively managed adjusting flows to maintain MVO2 >70% and rSO2 >45% for the entire duration of CPB (group B). Hemodynamic, metabolic, and clinical variables were compared within and between patient groups. Demographic variables were comparable in the two groups. In group A, the 20-min test allowed reduction of CPB flows greater than 10%, with no impact on pH, blood gas

exchange, and lactate. In group B, metabolic monitoring resulted in no significant variation of endpoint parameters, when compared with group A patients (standard CPB), except for a 10% reduction of nominal flows. There was no mortality and no neurologic morbidity in either group. Morbidity was comparable in the two groups, including: inotropic and/or mechanical circulatory support (8 vs. 1, group A vs. B, P = 0.07), reexploration for bleeding (1 vs. none, P = not significant [NS]), renal failure requiring dialysis (none vs. 1, P = NS), prolonged ventilation (9 vs. 4, P = NS), and sepsis (2 vs. 1, P = NS). The present study shows that normothermic CPB in neonates, infants, and young children can be safely managed exclusively by systemic and cerebral metabolic monitoring. This strategy allows reduction of at least 10% of predicted CPB flows under normothermia and may lay the ground for further tailoring of CPB parameters to individual patient needs.

54. Ogawa et al. (2015). **Load-distributing-band cardiopulmonary resuscitation for out-of-hospital cardiac arrest increases regional cerebral oxygenation: a single-center prospective pilot study**

Abstract: Background: Despite advances in therapeutic strategies and improved guidelines, morbidity and mortality rates for out-of-hospital cardiac arrest (OHCA) remain high. Especially, neurological prognosis is one of the most important problems even though brain protection therapy for patients with OHCA has improved greatly in recent years due to the development of emergency post-cardiac arrest interventions such as mild therapeutic hypothermia, early percutaneous coronary intervention, and extracorporeal cardiopulmonary resuscitation (CPR). Recently, cerebral regional oxygen saturation (rSO 2) has received attention as a method for evaluation of cerebral oxygenation. We have reported that conventional chest compression did not improve the rSO 2 of cardiac arrest patients if they did not achieve return of spontaneous circulation. It is, however, unclear whether a mechanical CPR device is helpful in improving rSO 2 . The purpose of this study was to evaluate the effects of load-distributing-band CPR (LDB-CPR) on rSO 2 .
Methods: In this prospective study, LDB-CPR was begun for OHCA with the AutoPulse TM device on patient arrival at hospital. During mechanical CPR, rSO 2 values were recorded continuously from the forehead of the patients. CPR for patients with OHCA was performed according to the Japan Resuscitation Council Guidelines 2010 except for using the AutoPulse TM instead of manual chest compression.
Results: From December 2012 to December 2013, 34 patients (mean age, 75.6 ± 12.8 years) with OHCA were included in this study. Duration of time from recognition of cardiac collapse to arrival to hospital was 31.0 ± 11.4 min. Compared with the rSO 2 value of 38.9 ± 0.7 % prior to starting LDB-CPR, rSO 2 values at 4, 8 and 12 minutes increased significantly after initiation of LDB-CPR (44.0 ± 0.9 %, 45.2 ± 0.8 %, and 45.5 ± 0.8 %, respectively, $p < 0.05$).
Conclusion: LDB-CPR significantly increased the rSO 2 of cardiac arrest patients during resuscitation.

55. Schewe et al. (2015). **Monitoring of cerebral oxygen saturation during resuscitation in out-of-hospital cardiac arrest: a feasibility study in a physician staffed emergency medical system**

Abstract: Background: Despite recent advances in resuscitation algorithms, neurological injury after cardiac arrest due to cerebral ischemia and reperfusion is one of the reasons for poor neurological outcome. There is currently no adequate means of measuring cerebral perfusion during cardiac arrest. It was the aim of this study to investigate the feasibility of measuring near infrared spectroscopy (NIRS) as a potential surrogate parameter for cerebral perfusion in patients with out-of-hospital resuscitations in a physician-staffed emergency medical service.
Methods: An emergency physician responding to out-of-hospital emergencies was equipped with a NONIN cerebral oximetry device. Cerebral oximetry values (rSO2) were continuously recorded during resuscitation and transport. Feasibility was defined as >80% of total achieved recording time in relation to intended recording time.
Results: 10 patients were prospectively enrolled. In 89.8% of total recording time, rSO2 values could be recorded (213 minutes and 20 seconds), thus meeting feasibility criteria. 3 patients experienced return of spontaneous circulation (ROSC). rSO2 during manual cardiopulmonary resuscitation (CPR) was lower in patients who did not

experience ROSC compared to the 3 patients with ROSC (31.6%, ± 7.4 versus 37.2% ± 17.0). ROSC was associated with an increase in rSO2. Decrease of rSO2 indicated occurrence of re-arrest in 2 patients. In 2 patients a mechanical chest compression device was used. rSO2 values during mechanical compression were increased by 12.7% and 19.1% compared to manual compression.
Conclusions: NIRS monitoring is feasible during resuscitation of patients with out-of-hospital cardiac arrest and can be a useful tool during resuscitation, leading to an earlier detection of ROSC and re-arrest. Higher initial rSO2 values during CPR seem to be associated with the occurrence of ROSC. The use of mechanical chest compression devices might result in higher rSO2. These findings need to be confirmed by larger studies.

56. Desmound et al. (2015). **Does near-infrared spectroscopy play a role in paediatric intensive care?**

Abstract: not available

57. Brigadoi et al. (2015). **Evaluating real-time image reconstruction in diffuse optical tomography using physiologically realistic test data**

Abstract: In diffuse optical tomography (DOT), real-time image reconstruction of oxy- and deoxy-haemoglobin changes occurring in the brain could give valuable information in clinical care settings. Although non-linear reconstruction techniques could provide more accurate results, their computational burden makes them unsuitable for real-time applications. Linear techniques can be employed under the assumption that the expected change in absorption is small. Several approaches exist, differing primarily in their handling of regularization and the noise statistics. In real experiments, it is impossible to compute the true noise statistics, because of the presence of physiological oscillations in the measured data. This is even more critical in real-time applications, where no off-line filtering and averaging can be performed to reduce the noise level. Therefore, many studies substitute the noise covariance matrix with the identity matrix. In this paper, we examined two questions: does using the noise model with realistic, imperfect data yield an improvement in image quality compared to using the identity matrix; and what is the difference in quality between online and offline reconstructions. Bespoke test data were created using a novel process through which simulated changes in absorption were added to real resting-state DOT data. A realistic multi-layer head model was used as the geometry for the reconstruction. Results validated our assumptions, highlighting the validity of computing the noise statistics from the measured data for online image reconstruction, which was performed at 2 Hz. Our results can be directly extended to a real application where real-time imaging is required.

58. Hu et al. (2015). **Comparison of motion correction techniques applied to functional near-infrared spectroscopy data from children**

Abstract: Motion artifacts are the most significant sources of noise in the context of pediatric brain imaging designs and data analyses, especially in applications of functional near-infrared spectroscopy (fNIRS), in which it can completely affect the quality of the data acquired. Different methods have been developed to correct motion artifacts in fNIRS data, but the relative effectiveness of these methods for data from child and infant subjects (which is often found to be significantly noisier than adult data) remains largely unexplored. The issue is further complicated by the heterogeneity of fNIRS data artifacts. We compared the efficacy of the six most prevalent motion artifact correction techniques with fNIRS data acquired from children participating in a language acquisition task, including wavelet, spline interpolation, principal component analysis, moving average (MA), correlation-based signal improvement, and combination of wavelet and MA. The evaluation of five predefined metrics suggests that the MA and wavelet methods yield the best outcomes. These findings elucidate the varied nature of fNIRS data artifacts and the efficacy of artifact correction methods with pediatric populations, as well as help inform both the theory and practice of optical brain imaging analysis.

59. Yamada et al. (2015). **Real-time system for extracting and monitoring the cerebral functional component during fNIRS measurements**

Abstract: Functional near-infrared spectroscopy (fNIRS) can non-invasively detect hemodynamic changes associated with cerebral neural activation in human subjects. However, its signal is often affected by changes in the optical characteristics of tissues in the head other than brain. To conduct fNIRS measurements precisely and efficiently, the extraction and realtime monitoring of the cerebral functional component is crucial. We previously developed methods for extracting the cerebral functional component—the multidistance optode arrangement (MD) method and the hemodynamic modality separation (HMS) method. In this study, we implemented these methods in a software used with the fNIRS system OEG- 17APD (Spectratech, Japan), and realized a real-time display of the extracted results. When using this system for human subject experiments, the baselines obtained with the MD and HMS methods were highly stabilized, whereas originally, the fNIRS signal fluctuated significantly when the subject moved. Through a functional experiment with repetitive single-sided hand clasping tasks, the extracted signals showed distinctively higher reproducibility than that obtained in the conventional measurements.

60. Chou et al. (2015). **Duration of Untreated Psychosis and Brain Function during Verbal Fluency Testing in First-Episode Schizophrenia: A Near-Infrared Spectroscopy Study**

Abstract: A longer duration of untreated psychosis (DUP) has been associated with poor clinical outcomes in patients with schizophrenia (SZ); however, it remains unclear whether this is due to neurotoxic effects of psychosis. The purpose of this study was to use near-infrared spectroscopy (NIRS) to investigate the influence of DUP on brain function using two verbal fluency tests (VFTs) in patients with first-episode SZ (FES). A total of 28 FES patients and 29 healthy controls (HC) underwent NIRS during VFTs. Group comparisons of cortical activity were made using two-tailed t-tests and the false discovery rate method. We then examined the associations between DUP and hemodynamic changes in each channel to identify any effects of DUP on brain cortical activity. During the letter VFT, the HC group exhibited significantly greater cortical activations over bilateral frontotemporal regions compared to FES patients. However, this distinction was not observed while performing a category version of the VFT. In addition, no associations between DUP and brain cortical activity were observed in the FES group during either VFT. In conclusion, we did not find an association between DUP and frontotemporal cortical activities. This might be because neurodevelopmental disturbances result in neurocognitive deficits long before psychotic symptoms onset.

61. Becerra et al. (2015). **Brain Measures of Nociception using Near Infrared Spectroscopy in Patients Undergoing Routine Screening Colonoscopy**

Abstract: Colonoscopy is an invaluable tool for screening and diagnosis of many colonic diseases. For most colonoscopies, moderate sedation is used during the procedure. However, insufflation of the colon produces a nociceptive stimulus that is usually accompanied by facial grimacing/groaning while under sedation. The objective of the current study was to evaluate whether a nociceptive signal elicited by colonic insufflation could be measured from the brain. Seventeen otherwise healthy patients (age 54.8±9.1; 6 female) undergoing routine colonoscopy (i.e., no history of significant medical conditions) were monitored using near-infrared spectroscopy (NIRS). Moderate sedation was produced using standard clinical protocols for midazolam and meperidine, titrated to effect. NIRS data captured during the procedure was analyzed offline to evaluate the brains' responses to nociceptive stimuli evoked by the insufflation events (defined by physician or observing patients' facial responses). Analysis of NIRS data revealed a specific, reproducible prefrontal cortex activity corresponding to times when patients grimaced. The pattern of the activation is similar to that previously observed during nociceptive stimuli in awake healthy individuals, suggesting that this approach may be used to evaluate brain activity evoked by nociceptive stimuli under sedation, when there is incomplete analgesia. While some patients

report recollection of procedural pain following the procedure, the effects of repeated nociceptive stimuli in surgical patients may contribute to postoperative changes including chronic pain. The results from this study indicate that NIRS may be a suitable technology for continuous nociceptive afferent monitoring in patients undergoing sedation and could have applications under sedation or anesthesia.

62. Yamada et al. (2015). **Real-time system for extracting and monitoring the cerebral functional component during fNIRS measurements**

Abstract: Functional near-infrared spectroscopy (fNIRS) can non-invasively detect hemodynamic changes associated with cerebral neural activation in human subjects. However, its signal is often affected by changes in the optical characteristics of tissues in the head other than brain. To conduct fNIRS measurements precisely and efficiently, the extraction and realtime monitoring of the cerebral functional component is crucial. We previously developed methods for extracting the cerebral functional component—the multidistance optode arrangement (MD) method and the hemodynamic modality separation (HMS) method. In this study, we implemented these methods in a software used with the fNIRS system OEG- 17APD (Spectratech, Japan), and realized a real-time display of the extracted results. When using this system for human subject experiments, the baselines obtained with the MD and HMS methods were highly stabilized, whereas originally, the fNIRS signal fluctuated significantly when the subject moved. Through a functional experiment with repetitive single-sided hand clasping tasks, the extracted signals showed distinctively higher reproducibility than that obtained in the conventional measurements.

63. Iwano et al. (2015). **Estimation of crosstalk in LED fNIRS by photon propagation Monte Carlo simulation**

Abstract: fNIRS (functional near-Infrared spectroscopy) can measure brain activity non-invasively and has advantages such as low cost and portability. While the conventional fNIRS has used laser light, LED light fNIRS is recently becoming common in use. Using LED for fNIRS, equipment can be more inexpensive and more portable. LED light, however, has a wider illumination spectrum than laser light, which may change crosstalk between the calculated concentration change of oxygenated and deoxygenated hemoglobins. The crosstalk is caused by difference in light path length in the head tissues depending on wavelengths used. We conducted Monte Carlo simulations of photon propagation in the tissue layers of head (scalp, skull, CSF, gray matter, and white matter) to estimate the light path length in each layers. Based on the estimated path lengths, the crosstalk in fNIRS using LED light was calculated. Our results showed that LED light more increases the crosstalk than laser light does when certain combinations of wavelengths were adopted. Even in such cases, the crosstalk increased by using LED light can be effectively suppressed by replacing the value of extinction coefficients used in the hemoglobin calculation to their weighted average over illumination spectrum.

64. Banerjee et al. (2015). **Effect of blood transfusion on intestinal blood flow and oxygenation in extremely preterm infants during first week of life**

Abstract: BACKGROUND: Extremely preterm infants receive frequent blood transfusions in the first week of life. The aim of this study was to measure the effect of blood transfusion on intestinal blood flow and oxygenation during the first week of life in extremely preterm infants.
STUDY DESIGN AND METHODS: Superior mesenteric artery (SMA) peak systolic velocity (PSV) and diastolic velocities were measured 30 to 60 minutes before and after transfusion. Splanchnic tissue hemoglobin index (sTHI), splanchnic tissue oxygenation index (sTOI), and splanchnic fractional tissue oxygen extraction (sFTOE) were measured continuously from 15 to 20 minutes before to after transfusion along with vital variables.
RESULTS: Twenty infants were studied (median gestational age, 26 weeks). Ten infants were partially fed (15-68 mL/kg/day). Heart rate and SaO2 remained unaltered; blood pressure increased significantly ($p < 0.01$) after

transfusion. Mean SMA PSV ($p = 0.63$) and diastolic velocity ($p = 0.65$) remained unaltered. Mean pretransfusion SMA PSV was similar in partially fed (0.78 m/sec) compared to unfed infants (0.52 m/sec; $p = 0.06$) and the response to transfusion was not dissimilar. There was a significant increase in sTHI (mean difference, 32.3%; $p < 0.01$) and sTOI (14.6%; $p = 0.03$) and decrease in sFTOE (22.1%; $p < 0.01$) after transfusion. There was no significant difference in sTHI or sTOI between fed and unfed infants and their response to transfusion.
CONCLUSIONS: Blood transfusion increased blood pressure and intestinal tissue oxygenation but did not alter blood flow velocities. Partial feeding had no impact on intestinal blood flow and tissue oxygenation changes.

65. Pourshoghi et al. (2015). **Cerebral reactivity in migraine patients measured with functional near-infrared spectroscopy**

Abstract: Background: There are two major theories describing the pathophysiology of migraines. Vascular theory explains that migraines resulted from vasodilation of meningeal vessels irritating the trigeminal nerves and causing pain. More recently, a neural theory of migraine has been proposed, which suggests that cortical hyperexcitability leads to cortical spreading depression (CSD) causing migraine-like symptoms. Chronic migraine requires prophylactic therapy. When oral agents fail, there are several intravenous agents that can be used. Understanding underlying causes of migraine pain would help to improve efficacy of migraine medications by changing their mechanism of action. Yet to date no study has been made to investigate the link between vascular changes in response to medications for migraine versus pain improvements. Functional near-infrared spectroscopy (NIRS) has been used as an inexpensive, rapid, non-invasive and safe technique to monitor cerebrovascular dynamics.
Method: In this study, a multi-distance near-infrared spectroscopy device has been used to investigate the cortical vascular reactivity of migraine patients in response to drug infusions and its possible correlation with changes in pain experienced. We used the NIRS on 41 chronic migraine patients receiving three medications: magnesium sulfate, valproate sodium, and dihydroergotamine (DHE). Patients rated their pain on a 1–10 numerical scale before and after the infusion.
Results: No significant differences were observed between the medication effects on vascular activity from near channels measuring skin vascularity. However, far channels—indicating cortical vascular activity—showed significant differences in both oxyhemoglobin and total hemoglobin between medications. DHE is a vasoconstrictor and decreased cortical blood volume in our experiment. Magnesium sulfate has a short-lived vasodilatory effect and increased cortical blood volume in our experiment. Valproate sodium had no significant effect on blood volume. Nonetheless, all three reduced patients' pain based on self-report and no significant link was observed between changes in cortical vascular reactivity and improvement in migraine pain as predicted by the vascular theory of migraine.
Conclusion: NIRS showed the potential to be a useful tool in the clinical setting for monitoring the vascular reactivity of individual patients to various migraine and headache medications.

66. Schytz et al. (2015). **Near infrared spectroscopy - investigations in neurovascular diseases**

Abstract: The purpose of this thesis was to explore and develop methods, where continuous wave near infrared spectroscopy (CW-NIRS) can be applied in different neurovascular diseases, in order to find biological markers that are useful in clinical neurology. To develop a new method to detect changes in cerebral blood flow (CBF), the first study investigated a multi-source detector separation configuration and indocyanine green (ICG) as a tracer to calculate a corrected blood flow index (BFI) value. The study showed no correlation between CBF changes measured by 133Xenon single photon emission computer tomography (133Xe-SPECT) and the corrected BFI value. It was concluded, that it was not possible to obtain reliable BFI data with the ICG CW-NIRS method. NIRS measurements of low frequency oscillations (LFOs) may be a reliable method to investigate vascular alterations in neurovascular diseases, but this requires an acceptable LFOs variation between hemispheres and over time in the healthy brain. The second study therefore investigated day-to-day and hemispheric variations in LFOs with NIRS. It was shown that NIRS might be useful in assessing LFOs between hemispheres, as well as

interhemispheric phase and gain directly and over time. Migraine may be associated with persistent impairment of neurovascular coupling, but there is no experimental evidence to support this. The third study therefore investigated interictal neurovascular coupling during a mental task by a Stroop test in migraine without aura (MO) patients, which is the most common type of migraine. The study showed intact neurovascular coupling in the prefrontal cortex outside of attacks in patients with MO. The fourth study aimed to investigate possible changes in LFOs amplitude following nitric oxide (NO) donor infusion in familial hemiplegic migraine (FHM), which is a rare Mendelian subtype of migraine with aura. This study showed increased LFOs amplitude only in FHM patients with co-existing common type of migraine, but not in patients with pure FHM phenotype. This suggests that the sensitivity to NO resides within the common migraine phenotypes rather than the FHM phenotype. Stimulation of the sphenopalatine ganglion (SPG) may lead to parasympathetic outflow and cause pain in cluster headache (CH). The fifth study therefore investigated pain and autonomic symptoms in relation to high or low SPG frequency stimulation in chronic CH patients. Cortical changes in oxygenated hemoglobin (HbO) were also recorded with NIRS and showed a moderate HbO increase, which was most pronounced on the ipsilateral CH side following high frequency stimulation. A possible application of NIRS to assess cerebral vascular changes due to sympathetic activity was investigated in obstructive sleep apnoea (OSA) patients, who have increased sympathetic activity and risk of stroke. Following successful continuous positive airway pressure (CPAP) therapy, OSA patients decreased their LFOs amplitude, which was interpreted as a marker of decreased sympathetic activity in cortical vessels. Finally, a novel hybrid technique, combining NIRS and ultrasound, was tested to detect CBF changes after acetazolamide injection in healthy volunteers using a cerebral flow index (CFI). The study showed an increase in CFI, which correlated with CBF measured with 133Xe-SPECT at 15 min. but not 60 min. Further methodological and explorative clinical studies are needed to assess the feasibility of ultrasound-tagged NIRS in clinical neurology. In summary, the thesis presents several novel approaches, by which NIRS may be used in clinical neurology, and potentials of NIRS to investigate complex mechanisms in neurovascular diseases.

67. Sugawara et al. (2015). **Regional Changes in Cerebral Oxygenation During Repeated Passive Movement Measured by Functional Near-infrared Spectroscopy**

Abstract: The aim of this study is to investigate the influence of passive movement repetition frequency at 1.5-Hz and 1-Hz on changes in cerebral oxygenation and assess the temporal properties of these changes using functional near-infrared spectroscopy (fNIRS). No significant differences in systemic hemodynamics were observed between resting and passive movement phases for either 1.5-Hz or 1-Hz trial. Changes in cortical oxygenation as measured by fNIRS in bilateral supplementary motor cortex (SMC), left primary motor cortex (M1), left primary somatosensory cortex (S1), and left posterior association area (PAA) during passive movement of the right index finger revealed greater cortical activity at only 1.5-Hz movement frequency. However, there were no significant differences in the time for peak oxyhemoglobin (oxyHb) among regions (bilateral SMC, 206.4 ± 14.4 s; left M1, 199.1 ± 14.8 s; left S1, 207.3 ± 9.4 s; left PAA, 219.1 ± 10.2 s). Therefore, our results that passive movement above a specific frequency may be required to elicit a changed in cerebral oxygenation, and the times of peak ΔoxyHb did not differ significantly among measured regions.

68. Tang et al. (2015). **Rapid analysis of textiles with portable near infrared spectroscopy**

Abstract: With certain textile materials being significantly cheaper than others, counterfeiting is rampant. Portable NIR spectroscopy enables screening of materials in the field, such as upon receipt or at ports and customs controls.

69. Suemori et al. (2015). **Cerebral oxygen saturation and tissue hemoglobin concentration as predictive markers of early postoperative outcomes after pediatric cardiac surgery**

Abstract: Background: Near-infrared spectroscopy (NIRS) provides an assessment of cerebral oxygenation and tissue hemoglobin concentration.
Aim: The aim of this study was to investigate whether the cerebral oxygenation and hemoglobin concentration measured with NIRS could predict outcomes after pediatric cardiac surgery.
Method: We conducted a retrospective observational study in 399 patients who underwent pediatric cardiac surgery. Associations were determined between postoperative outcome and preoperative and postoperative cerebral tissue oxygenation index (TOI), postoperative normalized tissue hemoglobin index (nTHI), concentration changes in oxygenated hemoglobin (Δ[HbO2]) and deoxygenated hemoglobin (Δ[HHb]).
Results: Thirty-nine children had major postoperative morbidity and 12 died. Using Spearman's correlation analysis, postoperative lower TOI and higher Δ[HHb] were associated with longer stays in the Intensive Care Unit (ICU) ($r = -0.48$, $P < 0.001$, $r = 0.31$, $P < 0.001$, respectively) and longer duration of intubation ($r = -0.48$, $P < 0.001$, $r = 0.31$, $P < 0.001$, respectively) and higher probability of death determined by the Risk Adjusted Classification for Congenital Heart Surgery (RACHS-1) ($r = -0.39$, $P < 0.001$, $r = 0.23$, $P < 0.001$, respectively). In multivariate regression analysis, postoperative TOI was independently associated with major morbidity and mortality and Δ[HHb] was independently associated with major morbidity. In receiver operating characteristic analysis, postoperative TOI and Δ[HHb] predicted major morbidity (Area under the curve [AUC] = 0.72, 0.68, respectively) and mortality (AUC = 0.81, 0.69, respectively).
Conclusion: Lower TOI or higher [HHb] at the end of surgery and higher RACHS-1 category predicted worse outcomes.

70. Ohdaira et al. (2015). **fNIRS-based analysis of temporal changes of brain activation during long-term conditioning with functional electrical stimulation**

Abstract: The number of patients who is suffering from paralysis due to aging, accidents, or brain injuries are increasing worldwide. Consequently, there is a compelling need for effective methods for the recovery of motor functions. One suggested effective rehabilitation method consists of stimulating brain activity to induce plasticity. Previous studies have reported that lost motor function and efficiency due to brain damage can be regained by repeatedly increasing and decreasing brain activation. Functional electrical stimulation (FES) has shown its effectiveness in the recovery of motor function. Brain activity usually decreases with the improvement of muscle control by FES. This study investigated the generality of brain responses during rehabilitation with FES in order to elucidate the recovery mechanism. We monitored the brain activity of ten healthy subjects with fNIRS over a ten-day period (one experiment per day) during which FES induced knee joint movements. The current results suggest that the observed increases and decreases of brain activity by FES are common in a healthy subject.

71. Huang et al. (2015). **Functional Connectivity during phonemic and semantic verbal fluency test: a multi-channel near infrared spectroscopy study**

Abstract: Verbal fluency tests (VFTs) are widely used frontal lobe neuropsychological tests. They have been frequently used in various functional brain mapping studies. There are two versions of VFTs based on the type of cue: the letter fluency task (LFT) and the category fluency task (CFT). However, the fundamental aspects of brain connectivity across the frontotemporal regions during the VFTs have not been elucidated. In this study, we hypothesized that differences in cortical functional connectivity over the left and right frontotemporal regions may be observed by means of multi-channel functional near-infrared spectroscopy (fNIRS) during the performance of LFT and CFT. Our results from fNIRS (ETG-4000) showed different patterns of brain functional connectivity during the two types of VFTs, which was consistent with the different cognitive requirements of each task. We demonstrate increased brain functional connectivity over the frontal and temporal regions during

the LFT than during the CFT; these results are in line with previous brain activity studies using fNIRS to demonstrate higher frontal and temporal region activation during LFT and CFT, with more pronounced frontal activation by the LFT.

72. Sandeep et al. (2015). **Changes in bispectral indesx (Bis) and Near Infrared Pectroscopy (NIRS) During Cardiopulmonary Bypass in Adult Patients Undergoing Coronary Artery Bypass Grafting**

Abstract: Background: Bispecteral Index and Near infrared Spectroscopy monitoring are standard monitoring regimen in anesthesia practice as well as in cardiac surgery. Both are important neuromonitoring modalities during cardiopulmonary bypass (CPB) due to high incidence of adverse neurologic outcome in post-operative period.
Aim: This observational and prospective study was designed to monitor the changes in Bi Specteral Index (BiS) and Near Infrared Spectroscopy (NIRS) at different steps of CPB in 40 patients undergoing Coronary artery bypass grafting (CABG).
Methodology: 40 patients of either sex in the range of age 30 to 70 years undergoing CABG with the use of CPB were studied. In all 40 patients both BiS and NIRS (right and left) electrodes were applied and values were studied at different steps of CPB.
Result: In this study BiS showed increased value at initiation of bypass because ofanaesthetic drug dilution and a lower BiS value was observed at stable hypothermic state (32°C) because of decreased metabolic activity of neuronal cells. As increased value of BiS at stable normothermic state (35°C) and at aortic cannula removal indicated increased metabolic activity and chances of awareness.
The NIRS right and left electrode values decreased from baseline values on initiation of bypass because of loss of pulsatile perfusion and haemodilution. Increased NIRS values were seen in stable hypothermic state (32°C) because of less oxygen uptake by the brain tissue. NIRS returned to its baseline values when physiologic circulation was resumed at the end of bypass.
Conclusion: From our study we conclude that low BiS values can indicate poor perfusion only but it takes some time as compared to NIRS values where sometimes low values of NIRS are related to hypocarbia (due to cerebral vasoconstriction), hypoperfusion, low Hb and Hematocrit values. NIRS can also detect cannula malposition and carotid stenosis if one of either two electrodes shows a low value, while a high value of one of the two electrodes can be because of a large old cerebral infarct. From this study it is recommended to use both BiS and NIRS monitor as neuromonitoring modalities to enhance patient safety and favorable outcome.

73. Koch et al. (2015). **Perioperative use of cerebral and renal near-infrared spectroscopy in neonates: a 24-h observational study**

Abstract: Background: Neonates undergoing surgery and intensive care still carry a significant morbidity and mortality often related to hypoxic/ischemic events; some of which may go undetected by conventional monitoring. Near-infrared spectroscopy (NIRS) is a noninvasive, continuous method of measuring regional tissue oxygen saturation, and may be used to supplement conventional monitoring to improve neonatal perioperative care. However, high costs and lack of evidence regarding improved outcomes have minimized wider perinatal use of NIRS. The aim of this study was to investigate the applicability of NIRS in neonates and premature infants undergoing noncardiac surgeries.
Method: Neonates were monitored with both cerebral and renal NIRS for 24 h after induction of anesthesia and compared with systemic blood pressure (BP), peripheral oxygen saturation (SpO2), and heart rate (HR).
Results: A total of 23 368 min of data were collected from 21 neonates. NIRS reported cerebral/renal hypoxia 2.8 (±8.3)%/19.3 (±25.4)% of the time intraoperatively and 9.6 (±17.0)%/9.9 (±18.9)% of the time postoperatively. A moderate positive correlation was found between SpO2 and NIRS (φcerebral = 0.371, φrenal = 0.542). BP showed a weaker positive correlation (φcerebral = 0.231, φrenal = 0.246), and HR no correlation (φcerebral = −0.083, φrenal = −0.029). NIRS reported hypoxia two to three times more frequently than SpO2, and SpO2 readings

were 10–15 s delayed compared to NIRS. Furthermore, NIRS appeared effective at detecting postoperative apnea.
Conclusion: Near-infrared spectroscopy is an easily applicable technique that appears effective at detecting hypoxic events and postoperative apneas in neonates. The high incidences of regional hypoxia reported by NIRS in this study imply that there is a need for a more specific regional cerebral and renal monitoring. Despite some practical and economical limitations, NIRS may be considered a useful supplement to perinatal perioperative intensive care.

74. Arai et al. (2015). **Altered frontal pole development affects self-generated spatial working memory in ADHD**

Abstract: Background: Spatial working memory (SWM) dysfunction is a feature of attention deficit hyperactivity disorder (ADHD). Previous studies suggested that behavioral performance in self-generated SWM improves through development in children with and without ADHD. Nevertheless, developmental changes in the neural underpinnings of self-generated SWM are unknown.
Method: Using near-infrared spectroscopy, hemodynamic activity in the prefrontal cortex (PFC) was measured in 30 children with ADHD (9.5 ± 1.6 years-old) and 35 TD children (9.0 ± 1.6 years-old) while they performed a self-generated SWM task. We then investigated correlations between age and behavioral performance, and between age and hemodynamic activity in the PFC for each group.
Results: Both groups showed a negative correlation with age and number of errors [ADHD: $r(28) = -0.37$, $p = 0.040$; TD: $r(33) = -0.59$, $p < 0.001$], indicating that self-generated SWM improves through development. The TD group showed a positive correlation between age and oxygenated hemoglobin in the frontal pole [10ch: $r(33) = 0.41$, $p = 0.013$; 11ch; $r(33) = 0.44$, $p = 0.008$] and bilateral lateral PFC [4ch: $r(33) = 0.34$, $p = 0.049$; 13ch; $r(33) = 0.54$, $p = 0.001$], while no significant correlation was found in the ADHD group. Furthermore, regression slopes for the frontal pole significantly differed between the TD and ADHD groups [10ch: $t(61) = 2.35$, $p = 0.021$; 11ch: $t(61) = 2.05$, $p = 0.044$].
Conclusion: Children with ADHD showed abnormalities in functional maturation of the frontal pole, which plays a role in manipulating and maintaining information associated with self-generated behavior.

75. Huhn et al. (2015). **Evidence of anhedonia and differential reward processing in prefrontal cortex among post-withdrawal patients with prescription opiate dependence**

Abstract: Anhedonia is an important but understudied element of a neuroadaptive model underlying vulnerability to relapse in opioid dependence. Previous research using fMRI has shown reduced activation to pleasant stimuli in rostral prefrontal cortex among heroin-dependent patients in early recovery. This study evaluated the presence of anhedonia among recently withdrawn prescription opiate dependent patients (PODP) in residential treatment compared to control subjects. Anhedonia was assessed using self-report, affect-modulated startle response (AMSR), and a cue reactivity task during which participant's rostral prefrontal cortex (RPFC) and ventrolateral prefrontal cortex (VLPFC) was monitored with functional near infrared spectroscopy (fNIRS). The cue reactivity task included three distinct categories of natural reward stimuli: highly palatable food, positive social situations, and intimate (non-erotic) interactions. PODP reported greater anhedonia on self-report (Snaith–Hamilton Pleasure Scale), and showed reduced hedonic response to positive stimuli in the AMSR task relative to controls. PODP also exhibited reduced neural activation in bilateral RPFC and left VLPFC in response to food images and reduced left VLPFC in response to images depicting positive social situations relative to controls. No differences were found for emotionally intimate stimuli. When patients were divided into groups based on the Snaith–Hamilton criteria for the presence or absence of anhedonia, patients endorsing anhedonia showed reduced neural responses to images depicting positive social stimuli and food relative to patients who did not endorse anhedonia. Activations were in areas of RPFC that support the retrieval of episodic memories. The results suggest the presence of anhedonia in a subsample of PODP.

76. Balconi et al. (2015). **Brain Activity (fNIRS) in Control State Differs from the Execution and Observation of Object-Related and Object-Unrelated Actions**

Abstract: The authors explored cortical correlates of action execution and observation, directly comparing control condition condition and execution–observation, using functional near-infrared spectroscopy. Transitive actions (meaningful gestures produced in presence of an object) or intransitive actions (meaningful gestures produced in absence of an object) were performed. Increased oxygenated hemoglobin levels were revealed for both action execution and action observation in premotor cortex, and sensorimotor cortex compared to control condition. However, a higher activity in motor areas was observed for action execution than motor observation. In contrast the posterior parietal cortex was similarly activated in case of both execution and observation task. Finally, it was shown that action execution and observation of transitive more than intransitive gestures was supported by similar parietal posterior areas. These findings support the hypothesis of a partial common network for observation and execution of action, and significant implications related to action types (transitive vs. intransitive).

77. Ardestani et al. (2015). **Modulation of Frontoparietal Neurovascular Dynamics in Working Memory**

Abstract: Our perception of the world is represented in widespread, overlapping, and interactive neuronal networks of the cerebral cortex. A majority of physiological studies on the subject have focused on oscillatory synchrony as the binding mechanism for representation and transmission of neural information. Little is known, however, about the stability of that synchrony during prolonged cognitive operations that span more than just a few seconds. The present research, in primates, investigated the dynamic patterns of oscillatory synchrony by two complementary recording methods, surface field potentials (SFPs) and near-infrared spectroscopy (NIRS). The signals were first recorded during the resting state to examine intrinsic functional connectivity. The temporal modulation of coactivation was then examined on both signals during performance of working memory (WM) tasks with long delays (memory retention epochs). In both signals, the peristimulus period exhibited characteristic features in frontal and parietal regions. Examination of SFP signals over delays lasting tens of seconds, however, revealed alternations of synchronization and desynchronization. These alternations occurred within the same frequency bands observed in the peristimulus epoch, without a specific correspondence between any definite cognitive process (e.g., WM) and synchrony within a given frequency band. What emerged instead was a correlation between the degree of SFP signal fragmentation (in time, frequency, and brain space) and the complexity and efficiency of the task being performed. In other words, the incidence and extent of SFP transitions between synchronization and desynchronization—rather than the absolute degree of synchrony—augmented in correct task performance compared with incorrect performance or in a control task without WM demand. An opposite relationship was found in NIRS: increasing task complexity induced more uniform, rather than fragmented, NIRS coactivations. These findings indicate that the particular features of neural oscillations cannot be linearly mapped to cognitive functions. Rather, information and the cognitive operations performed on it are primarily reflected in their modulations over time. The increased complexity and fragmentation of electrical frequencies in WM may reflect the activation of hierarchically diverse cognits (cognitive networks) in that condition. Conversely, the homogeneity in coherence of NIRS responses may reflect the cumulative vascular reactions that accompany that neuroelectrical proliferation of frequencies and the longer time constant of the NIRS signal. These findings are directly relevant to the mechanisms mediating cognitive processes and to physiologically based interpretations of functional brain imaging.

78. Jalil et al. (2015). **Near infrared image processing to quantitate and visualize oxygen saturation during vascular occlusion**

Abstract: The assessment of microcirculation spatial heterogeneity on the hand skin is the main objective of this work. Near-infrared spectroscopy based 2D imaging is a non-invasive technique for the assessment of tissue

oxygenation. The haemoglobin oxygen saturation images were acquired by a dedicated camera (Kent Imaging) during baseline, ischaemia (brachial artery cuff occlusion) and reperfusion. Acquired images underwent a preliminary restoration process aimed at removing degradations occurring during signal capturing. Then, wavelet transform based multiscale analysis was applied to identify edges by detecting local maxima and minima across successive scales. Segmentation of test areas during different conditions was obtained by thresholding-based region growing approach. The method identifies the differences in microcirculatory control of blood flow in different regions of the hand skin. The obtained results demonstrate the potential use of NIRS images for the clinical evaluation of skin disease and microcirculatory dysfunction.

79. Choi et al. (2015). **Comparison Between Phenylephrine and Dopamine in Maintaining Cerebral Oxygen Saturation in Thoracic Surgery: A Randomized Controlled Trial**

Abstract: Fluid is usually restricted during thoracic surgery, and vasoactive agents are often administered to maintain blood pressure. One-lung ventilation (OLV) decreases arterial oxygenation; thus oxygen delivery to the brain can be decreased. In this study, we compared phenylephrine and dopamine with respect to maintaining cerebral oxygenation during OLV in major thoracic surgery.
Sixty-three patients undergoing lobectomies were randomly assigned to the dopamine (D) or phenylephrine (P) group. The patients' mean arterial pressure was maintained within 20% of baseline by a continuous infusion of dopamine or phenylephrine. Maintenance fluid was kept at 5 mL/kg/h. The depth of anesthesia was maintained with desflurane 1MAC and remifentanil infusion under bispectral index guidance. Regional cerebral oxygen saturation (rScO2) and hemodynamic variables were recorded using near-infrared spectroscopy and esophageal cardiac Doppler.
The rScO2 was higher in the D group than the P group during OLV (OLV 60 min: 71±6% vs 63±12%; P=0.03). The number of patients whose rScO2 dropped more than 20% from baseline was 0 and 6 in the D and P groups, respectively (P=0.02). The D group showed higher cardiac output, but lower mean arterial pressure than the P group (4.7±1.0 vs 3.9±1.2 L/min; 76.7±8.1 vs 84.5±7.5 mm Hg; P=0.02, P=0.02). Among the variables, age, hemoglobin concentration, and cardiac output were associated with rScO2 by correlation analysis.
Dopamine was superior to phenylephrine in maintaining cerebral oxygenation during OLV in thoracic surgery.

80. Toyama et al. (2015). **Retrospective evaluation of the effect of carotid artery stenosis on cerebral oxygen saturation during off-pump coronary artery bypasses grafting in adult patients**

Abstract: Background: It is unknown whether cerebral oxygenation in patients with carotid artery stenosis (CAS) undergoing off-pump coronary artery bypass grafting (CABG) differs from that in patients without CAS. Thus, the effect of the presence of CAS ≥ 50 % on cerebral oxygenation during off-pump CABG in adult patients was evaluated retrospectively.
Methods: Eleven patients with CAS ≥ 50 % and 14 patients without CAS ≥ 50 % were enrolled. Regional cerebral tissue oxygen saturation (rSO2) was quantified using near-infrared spectroscopy. Mean arterial pressure, cardiac index, central venous pressure (CVP), and rSO2 at specific points were collected, and significant changes in each parameter were detected using repeated analysis of variance. Mean rSO2 and minimum rSO2 during anastomosis were analyzed by one-way analysis of variance. Multiple logistic regression analysis was used to estimate the odds ratio (OR) with 95 % confidence interval (CI) for cerebral desaturation (a decrease in rSO2 ≥ 10 % from preoperative value).
Results: Two patients with CAS ≥ 50 % who received complete carotid artery stenting preoperatively were excluded from the analyses. In both patients with and without CAS, a decrease in rSO2 and cardiac index and an increase in CVP were observed during anastomosis. Mean (SD) maximum decrease in rSO2 from preoperative value was 9.2 (12.7) % on the left side and 8.1 (11.7) % on the right side in patients with CAS ≥ 50 %, and 13.5 (11.3) % on the left side and 16.1 (9.8) % on the right side in patients without CAS ≥ 50 % (p = 0.316). Neurological complications were not identified in both patients with and without CAS ≥ 50 %. In multiple logistic regression analysis, CAS ≥ 50 % was not associated with an increased risk of cerebral desaturation (OR 0.160, 95

% CI 0.036–0.707, p = 0.016), and rSO2 decreased with decreasing cardiac index < 2.0 l/min/m2 (OR 3.287, 95 % CI 2.218–5.076, p < 0.001).
Conclusions: CAS ≥ 50 % was not an independent risk factor of cerebral desaturation during off-pump CABG. Our results suggest that maintaining cardiac output can prevent a decrease in cerebral oxygenation in both patients with and without CAS ≥ 50 %.

81. Michaelsen et al. (2015). **Calibration and optimization of 3D digital breast tomosynthesis guided near infrared spectral tomography**

Abstract: Calibration of a three-dimensional multimodal digital breast tomosynthesis (DBT) x-ray and non-fiber based near infrared spectral tomography (NIRST) system is challenging but essential for clinical studies. Phantom imaging results yielded linear contrast recovery of total hemoglobin (HbT) concentration for cylindrical inclusions of 15 mm, 10 mm and 7 mm with a 3.5% decrease in the HbT estimate for each 1 cm increase in inclusion depth. A clinical exam of a patient's breast containing both benign and malignant lesions was successfully imaged, with greater HbT was found in the malignancy relative to the benign abnormality and fibroglandular regions (11 μM vs. 9.5 μM). Tools developed improved imaging system characterization and optimization of signal quality, which will ultimately improve patient selection and subsequent clinical trial results.

82. Dehaes et al. (2015). **Perioperative cerebral hemodynamics and oxygen metabolism in neonates with single-ventricle physiology**

Abstract: Congenital heart disease (CHD) patients are at risk for neurodevelopmental delay. The etiology of these delays is unclear, but abnormal prenatal cerebral maturation and postoperative hemodynamic instability likely play a role. A better understanding of these factors is needed to improve neurodevelopmental outcome. In this study, we used bedside frequency-domain near infrared spectroscopy (FDNIRS) and diffuse correlation spectroscopy (DCS) to assess cerebral hemodynamics and oxygen metabolism in neonates with single-ventricle (SV) CHD undergoing surgery and compared them to controls. Our goals were 1) to compare cerebral hemodynamics between unanesthetized SV and healthy neonates, and 2) to determine if FDNIRS-DCS could detect alterations in cerebral hemodynamics beyond cerebral hemoglobin oxygen saturation (SO2). Eleven SV neonates were recruited and compared to 13 controls. Preoperatively, SV patients showed decreased cerebral blood flow (CBFi), cerebral oxygen metabolism (CMRO2i) and SO2; and increased oxygen extraction fraction (OEF) compared to controls. Compared to preoperative values, unstable postoperative SV patients had decreased CMRO2i and CBFi, which returned to baseline when stable. However, SO2 showed no difference between unstable and stable states. Preoperative SV neonates are flow-limited and show signs of impaired cerebral development compared to controls. FDNIRS-DCS shows potential to improve assessment of cerebral development and postoperative hemodynamics compared to SO2 alone.

Publications from the BORL, Zurich

83. Metz et al. (2015). **A New Approach for Automatic Removal of Movement Artifacts in Near-Infrared Spectroscopy Time Series by Means of Acceleration Data**

Abstract: Near-infrared spectroscopy (NIRS) enables the non-invasive measurement of changes in hemodynamics and oxygenation in tissue. Changes in light-coupling due to movement of the subject can cause movement artifacts (MAs) in the recorded signals. Several methods have been developed so far that facilitate the detection and reduction of MAs in the data. However, due to fixed parameter values (e.g., global threshold) none

of these methods are perfectly suitable for long-term (i.e., hours) recordings or were not time-effective when applied to large datasets. We aimed to overcome these limitations by automation, i.e., data adaptive thresholding specifically designed for long-term measurements, and by introducing a stable long-term signal reconstruction. Our new technique ("acceleration-based movement artifact reduction algorithm", AMARA) is based on combining two methods: the "movement artifact reduction algorithm" (MARA, Scholkmann et al. Phys. Meas. 2010, 31, 649–662), and the "accelerometer-based motion artifact removal" (ABAMAR, Virtanen et al. J. Biomed. Opt. 2011, 16, 087005). We describe AMARA in detail and report about successful validation of the algorithm using empirical NIRS data, measured over the prefrontal cortex in adolescents during sleep. In addition, we compared the performance of AMARA to that of MARA and ABAMAR based on validation data.

84. Holper et al. (2015). **Time–frequency dynamics of the sum of intra- and extracerebral hemodynamic functional connectivity during resting-state and respiratory challenges assessed by multimodal functional near-infrared spectroscopy**

Abstract: Monitoring respiratory processes is important for evaluating neuroimaging data, given their influence on time–frequency dynamics of intra- and extracerebral hemodynamics. Here we investigated the time–frequency dynamics of the sum of intra- and extracerebral hemodynamic functional connectivity states during hypo- and hypercapnia by using three different respiratory challenge tasks (i.e., hyperventilation, breath-holding, and rebreathing) compared to resting-state. The sum of intra- and extracerebral hemodynamic responses were assessed using functional near-infrared spectroscopy (fNIRS) within two regions of interest (i.e., the dorsolateral and the medial prefrontal cortex). Time–frequency fNIRS analysis was performed based on wavelet transform coherence to quantify functional connectivity in terms of positive and negative phase-coupling within each region of interest. Physiological measures were assessed in the form of partial end-tidal carbon dioxide, heart rate, arterial tissue oxygen saturation, and respiration rate. We found that the three respiration challenges modulated time–frequency dynamics differently with respect to resting-state: 1) Hyperventilation and breath-holding exhibited inverse patterns of positive and negative phase-coupling. 2) In contrast, rebreathing had no significant effect. 3) Low-frequency oscillations contributed to a greater extent to time–frequency dynamics compared to high-frequency oscillations. The results highlight that there exist distinct differences in time–frequency dynamics of the sum of intra- and extracerebral functional connectivity not only between hypo- (hyperventilation) and hypercapnia but also between different states of hypercapnia (breath-holding versus rebreathing). This suggests that a multimodal assessment of intra-/extracerebral and systemic physiological changes during respiratory challenges compared to resting-state may have potential use in the differentiation between physiological and pathological respiratory behavior accompanied by the psycho-physiological state of a human.

85. Plomgaard et al. (2015). **The SafeBoosC II randomised trial: treatment guided by near-infrared spectroscopy reduces cerebral hypoxia without changing early biomarkers of brain injury**

Abstract: Background: The SafeBoosC phase II multicentre randomised clinical trial investigated the benefits and harms of monitoring cerebral oxygenation by near-infrared spectroscopy (NIRS) combined with an evidence-based treatment guideline versus no NIRS-data and treatment as usual in the control group during the first 72 hours of life. The trial demonstrated a significant reduction in the burden of cerebral hypoxia in the experimental group. We now report the blindly assessed and analysed treatment effects on EEG (burst rate and spectral edge frequency 95%) and blood biomarkers of brain injury (S100ß, brain-fatty-acid-binding-protein, and neuroketal).
Methods: One-hundred-and-sixty-six extremely preterm infants were randomised to either experimental or control group. EEG was recorded at 64 hours of age and blood samples were collected at 6 and 64 hours of age.
Results: One-hundred-and-thirty-three EEGs were evaluated. The two groups did not differ regarding burst rates (experimental 7.2 versus control 7.7 burst/min.) or spectral edge frequency 95% (experimental 18.1 versus

control 18.0 Hertz). The two groups did not differ regarding blood S100ß, brain-fatty-acid-binding-protein, and neuroketal concentrations at 6 and 64 hours (n=123 participants).
Conclusions: Treatment guided by near-infrared spectroscopy reduced the cerebral burden of hypoxia without affecting EEG or the selected blood biomarkers.

86. Piera et al. (2015). **The SafeBoosC phase II clinical trial: an analysis of the interventions related with the oximeter readings**

Abstract: Background The SafeBoosC phase II randomised clinical trial recently demonstrated the benefits of a combination of cerebral regional tissue oxygen saturation (rStO2) by near-infrared spectroscopy (NIRS) and a treatment guideline to reduce the oxygen imbalance in extremely preterm infants.
Aims To analyse rStO2-alarm-related clinical decisions and their heterogeneity in the NIRS experimental group (NIRS monitoring visible) and their impact on rStO2 and SpO2.
Methods Continuous data from NIRS devices and the alarms (area under the curve of the rStO2 out of range had accumulated 0.2%h during 10 min), clinical data at discrete time points and interventions prompted by the alarms were recorded.
Results Sixty-seven infants had data that fulfilled the requirements for this analysis. 1107 alarm episodes were analysed. The alarm triggered a treatment guideline intervention in 25% of the cases; the type of intervention chosen varied among clinical sites. More than 55% of alarms were not followed by an intervention ('No action'); additionally, in 5% of alarms the rStO2 value apparently was considered non-reliable and the sensor was repositioned. The percentage of unresolved alarms at 30 min after 'No action' almost doubled the treatment guideline intervention ($p<0.001$). Changes in peripheral oxygen saturation (SpO2), were observed only after treatment guideline interventions.
Conclusions This study shows that 25% of rStO2 alarms were followed by a clinical intervention determined by the treatment guideline. However, the rStO2 and SpO2 returned to normal ranges after the intervention, supporting the notion that decisions taken by the clinicians were appropriate.