New papers about near-infrared spectroscopy (NIRS) and imaging (NIRI)
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Number of papers included: 121

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

1. Pouliot et al. (2014). Hemodynamic changes during posterior epilepsies: An EEG-fNIRS study

Abstract: Posterior epilepsies are mainly characterized clinically by visual symptoms. Functional near-infrared spectroscopy (fNIRS) is an emerging non-invasive imaging technique that has the potential to monitor hemodynamic changes during epileptic activity. Combined with electroencephalography (EEG), 9 patients with posterior epilepsies were recorded using EEG-fNIRS with large sampling (19 EEG electrodes and over 100 fNIRS channels). Spikes and seizures were carefully marked on EEG traces, and convolved with a standard hemodynamic response function for general linear model (GLM) analysis. GLM results for seizures (in 3 patients) and spikes (7 patients) were broadly sensitive to the epileptic focus in 7/9 patients, and specific in 5/9 patients with fNIRS deoxyhemoglobin responses lateralized to the correct lobe, and to plausible locations within the occipital or parietal lobes. This work provides evidence that EEG-fNIRS is a sensitive technique for monitoring posterior epileptic activity.


Abstract: Several methods of near infrared spectroscopy such as functional near infrared spectroscopy (fNIRS) and pulse oximetry have been applied for monitoring of tissue oxygenation or arterial oxygen saturation. Some vascular diseases can be diagnosed through measurements of tissue oxygenation. In this study, the temporal variation of oxygenation of calf muscle after exercise is studied by fNIRS. First, the accuracy of a low-cost fNIRS system is studied by measuring the oxygenation of a lipid phantom. Moreover, in-vivo study is performed to evaluate the precision of this system. Then, the variation of muscle oxygenation of four persons during exercise is measured and also the recovery time after walking/running is measured by this fNIRS system.

3. Laan et al. (2014). Modulation of Cerebral Blood Flow With Transcutaneous Electrical Neurostimulation (TENS) in Patients With Cerebral Vasospasm After Subarachnoid Hemorrhage

Abstract: Objectives: Transcutaneous electrical neurostimulation (TENS) and spinal cord stimulation have been shown to increase peripheral and cerebral blood flow. We postulate that certain pathological conditions attenuate cerebral autoregulation, which may result in a relative increase of the importance of neurogenic regulation of cerebral blood flow, which could be decreased by electrical modulation. We therefore assess the effects of TENS on cerebral blood flow velocities (CBFVs) and cerebral saturation in patients with cerebral vasospasm after subarachnoid hemorrhage (SAH). Materials and Methods: Cervical TENS was applied in 10 SAH patients with transcranial Doppler (TCD)-proven cerebral vasospasm. Measurements included plethysmography, near-infrared spectroscopy, capnography, and CBFVs by TCD. After determining the optimal frequency and current, patients were treated with cervical TENS for two periods of three days, with a pause of one day in between. Results: The TENS electrodes were not always tolerated by the patients. Higher frequencies demonstrated the most prominent combined effects. ETCO2 was 0.19% lower with TENS off than with TENS on
(p = 0.05). Mean arterial blood pressure and pulse were not significantly different over time. CBFV in MCA was decreased (p = 0.07) while cerebral oxygen saturation was increased (p = 0.01) after the use of TENS. Conclusions: Our data suggest improved cerebral blood flow when using cervical TENS in patients with cerebral vasospasm. Several factors could have attenuated the effects: the electrodes were poorly tolerated, ETCO2 increased during TENS, few vessels showed prolonged vasospasm, and overall flow velocities were low. Still, an on–off effect of TENS over time was detected.

4. Tsujii et al. (2014). **Right temporal activation differs between melancholia and nonmelancholic depression: A multichannel near-infrared spectroscopy study**

**Abstract:** The aim of this study was to determine whether melancholia differs from nonmelancholic depression in frontotemporal functioning by means of multichannel near-infrared spectroscopy. We recruited 32 major depressive disorder (MDD) patients with melancholic features (MDD-MF), 28 MDD patients with nonmelancholic features (MDD-NMF), and 24 healthy controls. Regional hemodynamic changes induced by a verbal fluency task (VFT) were monitored, and their correlations with depressive symptoms were examined. In comparison with the controls, significant differences were observed in mean oxygenated hemoglobin (oxy-Hb) changes induced by VFT in patients with MDD-MF in 25 channels (p = 0.000–0.047) and in those with MDD-NMF in 12 channels (p = 0.000–0.023). Moreover, patients with MDD-MF had significantly smaller mean oxy-Hb changes than those with MDD-NMF in 8 channels of the right temporal region (p = 0.001–0.048). No significant correlations were observed between mean oxy-Hb changes and the Hamilton rating scale for depression (HAMD) 17 total score in both groups of patients with MDD. On examining each item of HAMD17, psychomotor retardation in patients with MDD-MF showed a significant positive correlation with mean oxy-Hb changes in the right temporal region (ch43; ρ = 0.55; p = 0.001), whereas that in patients with MDD-NMF showed a significant negative correlation with mean oxy-Hb changes in the frontal and left temporal regions in 3 channels (ρ = −0.60 to −0.53; p = 0.000–0.004). In conclusion, our results indicate that melancholia is qualitatively distinct from nonmelancholic depression both clinically and biologically.

5. Nikulin et al. (2014). **Monochromatic Ultra-Slow (~ 0.1 Hz) Oscillations in the human electroencephalogram and their relation to hemodynamics**

**Abstract:** Previous studies demonstrated the presence of Monochromatic Ultra-Slow Oscillations (MUSO) in human EEG. In the present study we explored the biological origin of MUSO by simultaneous recordings of EEG, Near-Infrared Spectroscopy (NIRS), arterial blood pressure, respiration and Laser Doppler flowmetry. We used a head-up tilt test in order to check whether MUSO might relate to Mayer waves in arterial blood pressure, known to be enhanced by the tilting procedure. MUSO were detected in 8 out of 10 subjects during rest and showed a striking monochromatic spectrum (0.07–0.14 Hz). The spatial topography of MUSO was complex, showing multiple foci variable across subjects. While the head-up tilt test increased the relative power of Mayer waves, it had no effect on MUSO. On the other hand, the relative spectral power of 0.1 Hz oscillations in EEG, NIRS and blood pressure signals were positively correlated across subjects in the tilted condition. Eight subjects showed a coherence between MUSO and NIRS/arterial blood pressure. Moreover, MUSO at different electrode sites demonstrated coherence not reducible to volume conduction, thus indicating that MUSO are unlikely to be generated by one source. We related our experimental findings to known biological phenomena being generated at about 0.1 Hz, i.e.: arterial blood pressure, cerebral and skin vasomotion, respiration and neuronal activity. While no definite conclusion can yet be drawn as to an exact physiological mechanism of MUSO, we suggest that these oscillations might be of a rather extraneuronal origin reflecting cerebral vasomotion.

**Abstract:** Despite the practical implication of mild exercise, little is known about its influence on executive function and its neural substrates. To address these issues, the present study examined the effect of an acute bout of mild exercise on executive function and attempted to identify potential neural substrates using non-invasive functional near-infrared spectroscopy (fNIRS). Twenty-five young individuals performed a color-word matching Stroop task (CWST) and a two-dimensional scale to measure changes of psychological mood states both before and after a 10-minute exercise session on a cycle ergometer at light intensity (30% v·o2peak) and, for the control session, without exercise. Cortical hemodynamic changes in the prefrontal area were monitored with fNIRS during the CWST in both sessions. The acute bout of mild exercise led to improved Stroop performance, which was positively correlated with increased arousal levels. It also evoked cortical activations regarding Stroop interference on the left dorsolateral prefrontal cortex and frontopolar area. These activations significantly corresponded with both improved cognitive performance and increased arousal levels. Concurrently, this study provides empirical evidence that an acute bout of mild exercise improves executive function mediated by the exercise-induced arousal system, which intensifies cortical activation in task-related prefrontal sub-regions.

7. Storm et al. (2014). **Regional cerebral oxygen saturation after cardiac arrest in 60 patients—A prospective outcome study**

**Abstract:** Introduction: Non-invasive near-infrared spectroscopy (NIRS) offers the possibility to determine regional cerebral oxygen saturation (rSO2) in patients with cardiac arrest. Limited data from recent studies indicate a potential for early prediction of neurological outcome. Methods: Sixty cardiac arrest patients were prospectively enrolled, 22 in-hospital cardiac arrest (IHCA) and 38 out-of-hospital cardiac arrest (OHCA) patients respectively. NIRS of frontal brain was started after return of spontaneous circulation (ROSC) during admission to ICU and was continued until normothermia. Outcome was determined at ICU discharge by the Pittsburgh Cerebral Performance Category (CPC) and 6 months after cardiac arrest. Results: A good outcome (CPC 1–2) was achieved in 23 (38%) patients, while 37 (62%) had a poor outcome (CPC 3–5). Patients with good outcome had significantly higher rSO2 levels (CPC 1–2: rSO2 68%; CPC 3–5: rSO2 58%; p < 0.01). For good and poor outcome median rSO2 within the first 24 h period was 66% and 59% respectively and for the following 16 h period 68% and 59% (p < 0.01). Outcome prediction by area of rSO2 below a critical threshold of rsO2 = 50% within the first 40 h yielded 70% specificity and 86% sensitivity for poor outcome. Conclusion: On average, rSO2 within the first 40 h after ROSC is significantly lower in patients with poor outcome, but rSO2 ranges largely overlap between outcome groups. Our data indicate limited potential for prediction of poor outcome by frontal brain rSO2 measurements.

8. Martini et al. (2014). **Cerebral oxygenation and hemodynamic measurements during craniosynostosis surgery with near-infrared spectroscopy**

**Abstract:** Introduction: Focal pressure-related changes in brain perfusion and metabolism are discussed in single-suture craniosynostosis and brachycephalic cases (bicoronal synostosis). Raised intracranial pressure levels could be measured in some cases. In order to find possible loco-regional brain tissue changes during plastic surgery, we investigated oxygenation and perfusion parameters using non-invasive near-infrared spectroscopy (NIRS) probes. Methods: Twenty-two consecutively operated cases (mean age 7 months) with single-suture craniosynostosis were prospectively investigated using a NIRS probe (LEA©, O2C, white light 500–800 nm, laser NIR). Measurements for oxygen saturation (SO2), relative quantity of hemoglobin (rHb), blood flow, and blood flow velocity of the bilateral frontal, temporal, and parietal cortices were taken transosseously (prior to decompression) and epidurally directly after decompression as well as 15 and 30 min after decompression and before closure. Results: Twenty-two patients with scaphocephaly (11), trigonocephaly (6), anterior plagiocephaly (3), and brachycephaly (2) were investigated. SO2 was improving in all patient subgroups, showing the highest
levels in the fronto-temporal region; rHb improved in scaphocephalic, trigonocephalic, and brachycephalic children. Again, the highest values were found not only in the temporal but also in the frontal region and in brachycephalic patients also in the parietal cortex. Conclusion: These preliminary results of a new technology for brain tissue oxygenation and blood flow measurements suggest a regional compromise of cortical metabolism and circulation in patients with craniosynostosis.


Abstract: Strategy in short-term memory for serially presented pictures shifts gradually from a non-phonological to a phonological method as memory ability increases during typical childhood development. However, little is known about the development of this strategic change in children with attention-deficit/hyperactivity disorder (ADHD). To understand the neural basis of ADHD, we investigated short-term memory strategies using near-infrared spectroscopy. ADHD children aged from 6 to 12 years and age- and sex-matched control children were assessed in this study. Regional activity was monitored in the left ventrolateral prefrontal cortex to assess strategies used during short-term memory for visual or phonological objects. We examined the hypothesis that the strategic methods used would be correlated with memory ability. Higher memory ability and the phonological strategy were significantly correlated in the control group but not in the ADHD group. Intriguingly, ADHD children receiving methylphenidate treatment exhibited increased use of phonological strategy compared with those without. In conclusion, we found evidence of an altered strategy in short-term memory in ADHD children. The modulatory effect of methylphenidate indicates its therapeutic efficacy.


Abstract: Central and peripheral neural regulation of swallowing and aerodigestive reflexes is unclear in human neonates. Functional near infrared spectroscopy (NIRS) is a noninvasive method to measure changes in oxyhemoglobin (HbO) and deoxyhemoglobin (HbD). Pharyngoesophageal manometry permits evaluation of aerodigestive reflexes. Modalities were combined to investigate feasibility and to test neonatal frontoparietal cortical changes during pharyngoesophageal (visceral) stimulation and/or swallowing. Ten neonates (45.6 ± 3.0 wk postmenstrual age, 4.1 ± 0.5 kg) underwent novel pharyngoesophageal manometry concurrent with NIRS. To examine esophagus-brain interactions, we analyzed cortical hemodynamic response (HDR) latency and durations during aerodigestive provocation and esophageal reflexes. Data are presented as means ± SE or percent. HDR rates were 8.84 times more likely with basal spontaneous deglutition compared with sham stimuli (P = 0.004). Of 182 visceral stimuli, 95% were analyzable for esophageal responses, 38% for HDR, and 36% for both. Of analyzable HDR (n = 70): 1) HbO concentration (μmol/l) baseline 1.5 ± 0.7 vs. 3.7 ± 0.7 poststimulus was significant (P = 0.02), 2) HbD concentration (μmol/l) between baseline 0.1 ± 0.4 vs. poststimulus -0.5 ± 0.4 was not significant (P = 0.73), and 3) hemispheric lateralization was 21% left only, 29% right only, and 50% bilateral. During concurrent esophageal and NIRS responses (n = 66): 1) peristaltic reflexes were present in 74% and HDR in 61% and 2) HDR was 4.75 times more likely with deglutition reflex vs. secondary peristaltic reflex (P = 0.016). Concurrent NIRS with visceral stimulation is feasible in neonates, and frontoparietal cortical activation is recognized. Deglutition contrasting with secondary peristalsis is related to cortical activation, thus implicating higher hierarchical aerodigestive protective functional neural networks.

Abstract: Studies of brain connectivity have focused on two modes of networks: structural networks describing neuroanatomy and the intrinsic and evoked dependencies of functional networks at rest and during tasks. Each mode constrains and shapes the other across multiple timescales and each also shows age-related changes. Here we argue that understanding how brains change across development requires understanding the interplay between behavior and brain networks: changing bodies and activities modify the statistics of inputs to the brain; these changing inputs mold brain networks; and these networks, in turn, promote further change in behavior and input.

12. Schmitz et al. (2014). Feasibility of long-term cerebral and peripheral regional tissue oxygen saturation measurements

Abstract: The aim of this study was to analyse the feasibility of long-term measurements of cerebral (crSO2) and peripheral (prSO2) regional tissue oxygen saturation on the first day of life by determining the amount of artefacts and their influence on rSO2. Near infrared spectroscopy (NIRS) measurements were performed fronto-parietal left (crSO2) and on the right forearm (prSO2). Arterial oxygen saturation (SpO2) was measured by pulse oximetry on the right wrist. Three criteria (C) were defined to identify artefacts (C1: missing values, C2: rSO2 jumping >15%, C3: rSO2 ≥ SpO2). The number of artefacts as a percentage of measurement time and mean rSO2 was calculated after the introduction of each criterion. Measurements were performed in 40 neonates. The number of artefacts in crSO2 measurements was similar after introduction of C1 (7.37 ± 4.64%) and after introduction of all criteria (8.89 ± 4.59%). The number of artefacts in prSO2 measurements after introduction of C1 was 10.83 ± 4.21%, and after introduction of all criteria significantly higher with 17.78 ± 4.27%. After introduction of C1, further criteria did not significantly change rSO2: crSO2 (78.6 ± 1.3% versus 78.5 ± 1.2%) and prSO2 (83.7 ± 0.9% versus 83.5 ± 0.9%). In conclusion, long-term NIRS measurements of crSO2 and prSO2 are feasible, since most artefacts are due to missing values and therefore easy to recognize.


Abstract: Evaluating alterations in brain activity in response to pain stimulus can help understand the mechanisms underlying pain perception. We measured oxygenated hemoglobin (oxy-Hb) levels using functional near-infrared spectroscopy (fNIRS) in order to assess prefrontal cortex activation after inducing a pain stimulus to the gingiva. Twenty-three right-handed, healthy male subjects (mean age: 29.3 ± 3.6 years) were subjected to a mild pain stimulus to the tissue around the right maxillary central incisor. The periodontal pain stimulus (PPS) was elicited from a pocket probe, and a multi-channel fNIRS system with its accompanying 22-channel probes was used for measuring oxy-Hb levels. Mean oxy-Hb levels for each channel were calculated on the basis of values obtained at rest and during the PPS load, for 1 min each. The change in oxy-Hb level was calculated by subtracting oxy-Hb at rest from oxy-Hb levels during PPS load. Oxy-Hb levels in each channel during both conditions were then compared using the paired t-test and Bonferroni correction. Pain stimulation caused oxy-Hb levels to decrease in virtually all areas of the prefrontal cortex, particularly, in the superior frontal gyrus, the middle frontal gyrus, and the orbital part of the superior, middle, and inferior frontal gyrus, on the brain side contralateral to the pain load. This measurement could prove beneficial as an index for objective pain evaluation.

**Abstract:** The wondrous innovations bound to the introduction of functional near-infrared spectroscopy in cognitive neuroscience are characterized by a multifaceted nature, ranging from technological improvements to sophisticated signal processing methods; the outstanding progress enabled scientists to investigate a variety of hard-to-test clinical populations and to successfully employ optical imaging in fields that were almost unimaginable twenty years ago. Here we illustrate how the emerging use of fNIRS methodologies might represent a drawing power in a variety of challenging experimental and medical contexts; we expect in the near future a wide increase of the use of wireless fNIRS, especially in children and in particular clinical populations, as well as a striking progress of fNIRS-BCI and hybrid BCI systems for neurofeedback and neurorehabilitation. These emerging trends might dramatically foster the future potential of fNIRS in brain sciences, provided that they are properly supported by a significant progress in signal processing and cognitive neuroscience.


**Abstract:** Aims: Near-infrared spectroscopy has the potential for aiding the diagnosis of major depressive disorder. The purpose of this study was to systematically review the evidence from observational studies regarding the use of near-infrared spectroscopy in patients with major depressive disorder and to identify the characteristic pattern of prefrontal lobe activity in major depressive disorder. Methods: medline, PubMed, Cochrane Library and Web of Science databases were searched in December 2013. All case–control studies were included. The quality of evidence was examined using the Newcastle–Ottawa Quality Assessment Scale. The primary outcome measures were the mean oxygenated and deoxygenated hemoglobin alterations of the cerebral cortex during cognitive activation periods. The standard mean difference for the overall pooled effects across the included studies was estimated using random or fixed effect models. The primary outcome measures were included in the meta-analysis. Results: Fourteen studies met the inclusion criteria. Six studies (n = 692 participants) were included in the analysis of the mean oxygenated hemoglobin alterations; the pooled mean standardized difference was −0.74 (95% confidence interval, −0.97 to −0.52), indicating that patients with major depressive disorder were associated with attenuated increase in oxygenated hemoglobin during cognitive activation in the prefrontal regions compared to healthy controls. Five studies (n = 668 participants) were included in the analysis of mean deoxygenated-hemoglobin changes; the pooled standardized mean difference was 0.18 (95% confidence interval, −0.20 to 0.56). Conclusions: Using near-infrared spectroscopy measurements, we observed that compared to healthy subjects, patients with major depressive disorder had significantly lower prefrontal activation during cognitive tasks.

16. Svenmarker et al. (2014). **Regional changes in cerebral blood flow oxygenation can indicate global changes in cerebral blood flow during coronary artery occlusion in juvenile pigs**

**Abstract:** Near infrared spectroscopy (NIRS) is a widely employed method for assessment of regional cerebral oxygenation (RcStO2). RcStO2 values are expected to vary with changes in the relative amount of oxyhaemoglobin. The present experimental study aimed to assess the response of RcStO2 to controlled alterations of carotid blood flow (CQ). Landrace pigs were anesthetized followed by surgical preparation. Cyclic variations in cardiac output were accomplished by intermittently occluding the main stem of the left coronary artery. A flow measurement probe for assessing CQ was placed around the left carotid artery. One NIRS probe was placed on the left ipsilateral forehead to assess regional cerebral oximetry. Simultaneous registration of CQ and RcStO2 was conducted. There was a strong correlation for variation in CQ and RcStO2 signal values. Based on coherence analysis the fraction of power of the RcStO2 that was coherent with the CQ signal reached 0.84 ± 0.12 (P < 0.05) for frequencies lower than 0.1 Hz. The agreement of the sample-to-sample co-variation, as
assessed by the Pearson correlation coefficient, was $0.83 \pm 0.08$ ($P < 0.05$). One explanatory component for variations in cerebral oxygenation verified by NIRS should be attributed to variations in the cerebral blood flow.

17. Hong et al. (2014). **Age-related spatiotemporal reorganization during response inhibition**

**Abstract:** As a key high-level cognitive function in human beings, response inhibition is crucial for adaptive behavior. Previous neuroimaging studies have shown that older individuals exhibit greater neural activation than younger individuals during response inhibition tasks. This finding has been interpreted within a neural compensation framework, in which additional neural resources are recruited in response to age-related cognitive decline. Although this interpretation has received empirical support, the precise event-related temporal course of this age-related compensatory neural response remains unexplored. In the present study, we conducted source analysis on inhibition-related ERP components (i.e., N2 and P3) that were recorded while healthy younger and older adults participated in a visual Go/NoGo task. We found that older adults showed increased source current densities of the N2 and P3 components than younger adults, which support previous hemodynamic findings. Further, such age-related differences in neural activation were successfully separated between the N2 and P3 periods by source localization analysis. Interestingly, the increased activations in older adults were primarily localized to the right precentral and postcentral gyri during the N2 period, which shifted to the right dorsolateral prefrontal cortex and the right inferior frontal gyrus during the P3 period. Taken together, our results clearly illustrate the spatiotemporal dynamics of age-related functional brain reorganization, and further specify the exact temporal course at the millisecond scale by which age-related compensatory neural responses occur during response inhibition.

18. Bahnmüller et al. (2014). **NIRS in motion—unraveling the neurocognitive underpinnings of embodied numerical cognition**

**Abstract:** The central representation of numerical cognition is commonly considered an abstract magnitude representation serving as one key precursor for higher mathematical thinking. However, recent research indicates that the representation might not be purely abstract. In fact, accumulating evidence suggests that numerical representations are rooted in and shaped by specific motor activities and sensory-bodily experiences and, therefore, are influenced by so-called embodied numerical representations. If we want to understand how numerical understanding develops, it is crucial to elucidate the basic cognitive tools with which we develop a sense of number. We argue that it is necessary to address this issue on both a behavioral and a neural level. Contrasting the view of functional magnetic resonance imaging (fMRI) being the generally preferable neuroimaging technique, we argue that particularly in embodied cognition, restrictions and benefits of different imaging methods should guide the chosen research question. In our opinion, near-infrared spectroscopy (NIRS) is optimally suited to investigate embodied cognition paradigms that explicitly involve motion. In the following, recent research will be outlined showing that numerical cognition is not purely abstract, but influenced by embodied representations. NIRS will then be introduced as a feasible technique for the investigation of embodied cognitions. Since research in this domain is largely restricted to the perception of embodied experiences, but fails to address motion itself, we will finally argue that NIRS offers a good opportunity to fill this research gap.

19. He et al. (2014). **Diffuse optical tomography to monitor the photocoagulation front during interstitial photothermal therapy: Numerical simulations and measurements in tissue-simulating phantoms**

**Abstract:** Near-infrared interstitial photothermal therapy (PTT) is currently undergoing clinical trials as an alternative to watchful waiting or radical treatments in patients with low/intermediate-risk focal prostate cancer. Currently, magnetic resonance imaging (MRI)-based thermography is used to monitor thermal energy delivery and determine indirectly the completeness of the target tumor destruction while avoiding damage to
adjacent normal tissues, particularly the rectal wall. As an alternative, transrectal diffuse optical tomography (TRDOT) is being developed to image directly the photocoagulation boundary based on the changes in tissue optical properties, particularly scattering. An established diffusion-theory finite-element software platform was used to perform forward simulations to determine the sensitivity of changes in the optical signal resulting from a growing coagulated lesion with optical scattering contrast, for varying light source-detector separations in both longitudinal and transverse imaging geometries. The simulations were validated experimentally in tissue-simulating phantoms using an existing continuous-wave TRDOT system, in a configuration that is representative of one potential intended clinical use. This provides critical guidance for the optimum design of the transrectal applicator probe, in terms of achieving maximum sensitivity to the presence of the coagulation boundary and, consequently, the highest accuracy in determining the boundary location relative to the rectal wall.


Abstract: Seizures in the newborn brain represent a major challenge to neonatal medicine. Neonatal seizures are poorly classified, under-diagnosed, difficult to treat and are associated with poor neurodevelopmental outcome. Video-EEG is the current gold-standard approach for seizure detection and monitoring. Interpreting neonatal EEG requires expertise and the impact of seizures on the developing brain remains poorly understood. In this case study we present the first ever images of the haemodynamic impact of seizures on the human infant brain, obtained using simultaneous diffuse optical tomography (DOT) and video-EEG with whole-scalp coverage. Seven discrete periods of ictal electrographic activity were observed during a 60 minute recording of an infant with hypoxic–ischaemic encephalopathy. The resulting DOT images show a remarkably consistent, high-amplitude, biphasic pattern of changes in cortical blood volume and oxygenation in response to each electrographic event. While there is spatial variation across the cortex, the dominant haemodynamic response to seizure activity consists of an initial increase in cortical blood volume prior to a large and extended decrease typically lasting several minutes. This case study demonstrates the wealth of physiologically and clinically relevant information that DOT–EEG techniques can yield. The consistency and scale of the haemodynamic responses observed here also suggest that DOT–EEG has the potential to provide improved detection of neonatal seizures.

21. Lv et al. (2014). Effect of vascular haemoglobin concentrations on ultrasound-guided diffuse optical tomography in differentiating benign from malignant breast lesions

Abstract: Objectives: Ultrasound-guided diffuse optical tomography (US-DOT) can potentially detect breast carcinomas by measuring total tumour haemoglobin concentrations (TTHC). The purpose of this study was to evaluate whether vascular haemoglobin concentrations (VHC) affect the ability of US-DOT to distinguish breast carcinomas from benign. Materials and methods: In 85 women (97 palpable lesions) referred for core breast biopsy, we measured VHC with a complete blood count and calculated TTHCs for each lesion with US-DOT. Anaemia was defined as a VHC less than 120.0 g/L. Results: Mean TTHCs were significantly higher in malignant lesions (n = 53) than in benign lesions (n = 44), regardless of whether the lesions were from women with anaemia (TTHC, 248.5 vs. 123.3 μmol/L; P = 0.001) or from those without (TTHC, 229.7 vs. 173.9 μmol/L; P = 0.016). A cut-off TTHC of 155.1 μmol/L provided 81.3 % sensitivity, 81.8 % specificity and 81.5 % accuracy for detecting malignant tumours in women with anaemia and 78.4 % sensitivity, 54.5 % specificity and 67.1 % accuracy for women without. There was no significant difference in sensitivity (P = 0.813), specificity (P = 0.108) and accuracy (P = 0.162) between the anaemic group and the non-anaemic group. Conclusions: Vascular haemoglobin concentrations did not affect the ability of US-DOT to differentiate breast carcinomas from benign lesions.

**Abstract:** Neuroimaging studies of post-traumatic stress disorder (PTSD)-related memory impairments have consistently implicated abnormal activities in the frontal and parietal lobes. However, most studies have used block designs and could not dissociate the multiple phases of working memory. In this study, the involvement of the prefrontal cortex in working memory phases was assessed among veterans with PTSD and age-/gender-matched healthy controls. Multichannel functional near infrared spectroscopy (fNIRS) was utilized to measure prefrontal cortex hemodynamic activations during memory of neutral (i.e., not trauma-related) forward and backward digit span tasks. An event-related experimental design was utilized to dissociate the different phases (i.e., encoding, maintenance and retrieval) of working memory. The healthy controls showed robust hemodynamic activations during the encoding and retrieval processes. In contrast, the veterans with PTSD were found to have activations during the encoding process, but followed by distinct deactivations during the retrieval process. The PTSD participants, but not the controls, appeared to suppress prefrontal activity during memory retrieval. This deactivation was more pronounced in the right dorsolateral prefrontal cortex during the retrieval phase. These deactivations in PTSD patients might implicate an active inhibition of dorsolateral prefrontal neural activity during retrieval of working memory.

23. Abookasis et al. (2014). **Exploring diazepam’s effect on hemodynamic responses of mouse brain tissue by optical spectroscopic imaging**

**Abstract:** In this study, a simple duel-optical spectroscopic imaging apparatus capable of simultaneously determining relative changes in brain oxy-and deoxy-hemoglobin concentrations was used following administration of the anxiolytic compound diazepam in mice with strong dominant (Dom) and submissive (Sub) behavioral traits. Three month old mice (n = 30) were anesthetized and after 10 min of baseline imaging, diazepam (1.5 mg/kg) was administered and measurements were taken for 80 min. The mouse head was illuminated by white light based LED's and diffused reflected light passing through different channels, consisting of a bandpass filter and a CCD camera, respectively, was collected and analyzed to measure the hemodynamic response. This work's major findings are threefold: first, Dom and Sub animals showed statistically significant differences in hemodynamic response to diazepam administration. Secondly, diazepam was found to more strongly affect the Sub group. Thirdly, different time-series profiles were observed post-injection, which can serve as a possible marker for the groups' differentiation. To the best of our knowledge, this is the first report on the effects of an anxiolytic drug on brain hemodynamic responses in mice using diffused light optical imaging.


**Abstract:** Background: Near infrared spectroscopy imaging is one of the new techniques used for investigating structural and functionality of different body tissues. This is done by injecting light into the medium and measuring the photon intensity at the surface of the tissue. Method: In this paper the different medical applications, various imaging and simulation techniques of NIRS imaging is described. Each method is introduced and discussed. Then, the optimized model is prepared for numerical simulations. In this paper, the finite element method is used for solving the diffusion equation numerically. Results: Diffusion equation was solved for realistic human head model using finite element approach for a point light source and time resolved case. The photon intensity distribution in different head layers has been shown and the intensity orientation via the CSF layer has been illustrated. Conclusion: Simulating the photon transformation inside the tissue is essential for investigating the NIRS imaging technique. The finite element approach is a fast and accurate method for simulating this fact. The time resolved approach of this technique could illustrate the photon migration and intensity orientation in the tissue for time dependent light sources in tissues.
25. Ichikawa et al. (2014). **Novel method to classify hemodynamic response obtained using multi-channel fNIRS measurements into two groups: exploring the combinations of channels**

**Abstract:** Near-infrared spectroscopy (NIRS) in psychiatric studies has widely demonstrated that cerebral hemodynamics differs among psychiatric patients. Recently we found that children with attention-deficit/hyperactivity disorder (ADHD) and children with autism spectrum disorders (ASD) showed different hemodynamic responses to their own mother's face. Based on this finding, we may be able to classify the hemodynamic data into two those groups and predict to which diagnostic group an unknown participant belongs. In the present study, we proposed a novel statistical method for classifying the hemodynamic data of these two groups. By applying a support vector machine (SVM), we searched the combination of measurement channels at which the hemodynamic response differed between the ADHD and the ASD children. The SVM found the optimal subset of channels in each data set and successfully classified the ADHD data from the ASD data. For the 24-dimensional hemodynamic data, two optimal subsets classified the hemodynamic data with 84% classification accuracy, while the subset contained all 24 channels classified with 62% classification accuracy. These results indicate the potential application of our novel method for classifying the hemodynamic data into two groups and revealing the combinations of channels that efficiently differentiate the two groups.

26. Ichikawa et al. (2014). **Basic Study for New Assistive Technology Based on Brain Activity During Car Driving**

**Abstract:** The purpose of this research is develop assistive robots and apparatuses. There is a pressing need to develop new systems that assist and act for car driving and wheelchairs for the elderly as the population ages. In developing systems, it is thought to be important to examine behaviors spatial recognition. Experiments have therefore been performed to examine human spatial perceptions, especially left- and rightside visual recognition, while cars being driven using near-infrared spectroscopy (NIRS). Previous research found significant differences in the dorsolateral prefrontal cortex in the left cranial hemisphere during virtual driving and actual driving tasks. This paper discusses the measurement of brain activity during car driving. A detailed analysis was performed by segmentalizing brain activity during driving based on the motion of subjects, and we report on the relationship between brain activity and movement perception during driving.

27. Bahnmueller et al. (2014). **NIRS in motion—unraveling the neurocognitive underpinnings of embodied numerical cognition**

**Abstract:** The central representation of numerical cognition is commonly considered an abstract magnitude representation serving as one key precursor for higher mathematical thinking. However, recent research indicates that the representation might not be purely abstract. In fact, accumulating evidence suggests that numerical representations are rooted in and shaped by specific motor activities and sensory-bodily experiences and, therefore, are influenced by so-called embodied numerical representations. If we want to understand how numerical understanding develops, it is crucial to elucidate the basic cognitive tools with which we develop a sense of number. We argue that it is necessary to address this issue on both a behavioral and a neural level.

28. Okahashi et al. (2014). **An fNIRS-Based Study on Prefrontal Cortex Activity during a Virtual Shopping Test with Different Task Difficulties in Brain-Damaged Patients**

**Abstract:** We developed a Virtual Shopping Test with three different task levels for assessment of daily cognitive function using virtual reality technology. The objective of present study was to investigate the difference on task performance, brain activation and subjective assessment in relation to the difficulty levels of the tasks. Subjects were asked to buy specific 2 items in Task 1, 4 items in Task 2, and 6 items in Task 3 at a virtual mall. The tasks and questionnaires were conducted on 10 convalescent brain-damaged patients and 6
healthy young adults. Hemodynamic changes in the prefrontal cortex (PFC) during activation due to the tasks were examined using functional near-infrared spectroscopy. As the result, the mean total time was significantly longer for the patients than for healthy subjects. PFC showed a greater response for related Task 2 than Task 1 in shopping and moving phase in patient group. The patients evaluated Tasks 1 and 2 are more difficult and bring more psychological load than healthy adults subjectively. That is, although the healthy adults did not show large difference in their task performances as well as PFC responses, they can evaluate the differences between three task levels, subjectively, while which could not be for the patients means that patients could not distinguish the difference of the tasks, subjectively. The results suggest that 4-item shopping task might be enough difficulty level that causes brain activation for the brain-damaged patients.

29. Lundblad et al. (2014). *Reduction of cerebral mean blood flow velocity and oxygenation after high-volume (1.5 ml kg\(^{-1}\)) caudal block in infants*

Abstract: Background: We have recently described a bi-directional bulk flow of cerebrospinal fluid (CSF) (coined ‘the CSF rebound mechanism’) after the use of high-volume caudal block in infants, which may explain the secondary longitudinal spread of the block. If important the initial cephalad transfer of CSF should be of such a magnitude that it would cause a transient reduction in cerebral blood flow (CBF) and cerebral oxygenation. The primary aim of this observational study was to delineate the magnitude of the reduction of CBF velocity (CBFV) associated with high-volume caudal block in infants. Methods: Ultrasound Doppler measurements of CBFV in the middle cerebral artery and also haemodynamic parameters and cerebral regional oxygenation (CRSO2) were followed during 5 min after the initial caudal injection (1.5 ml kg\(^{-1}\), ropivacaine 0.2%) in 12 infants <3 months of age. Results: The caudal injection was associated with immediate and major reductions in CBFV indicating a concomitant reduction in CBF. A significant reduction of cerebral regional oxygenation CRSO2 was also observed. Systemic haemodynamic parameters were unchanged during the observation period. Conclusion: High-volume caudal block causes a biphasic change in CBFV and was also found to affect cerebral oxygenation. Our findings lend further support to ‘the CSF rebound mechanism’ for secondary spread of high-volume caudal block.


Abstract: Optical recording technique overtakes neural recording technique for simplicity, non-ionization, portability, non-invasiveness and cost effectiveness. Many optical techniques like FMRI, DOT, SPR, ERP and PPG are in use now-a-days. Among them, Near Infrared Spectroscopy become popular because of its high temporal resolution and reasonable spatial resolution. Keeping this in mind, NIRS can be used to detect the brain activities. As an initiative, a prototype head band for NIRS has been developed and it can be used to detect sinusitis in an easy manner. Signals have been captured from various persons and their statistical parameters have been analyzed. Signals have been captured before and after sleep for normal and sinusitis persons and the difference between them in various statistical parameters were clearly identified. Spectral analysis was done using parametric and non-parametric methods and the best method was identified for detecting sinusitis. Best method is used to analyze normal and sinusitis persons and the increase in peak value and dynamic range for sinusitis person is identified from the waveform.

31. Roberts et al. (2014). *Differences in prefrontal blood oxygenation during an acute multitasking stressor in ecstasy polydrug users*

Abstract: Background: Cognitive deficits are well documented in ecstasy (3,4-methylenedioxymethamphetamine; MDMA) users, with such deficits being taken as evidence of dysregulation of the serotonin (5-hydroxytryptamine; 5-HT) system. More recently neuroimaging has been used to corroborate these deficits. The present study aimed to assess multitasking performance in ecstasy polydrug users, polydrug users
and drug-naive individuals. It was predicted that ecstasy polydrug users would perform worse than non-users on the behavioural measure and this would be supported by differences in cortical blood oxygenation. Method: In the study, 20 ecstasy-polydrug users, 17 polydrug users and 19 drug-naive individuals took part. On day 1, drug use history was taken and questionnaire measures were completed. On day 2, participants completed a 20-min multitasking stressor while brain blood oxygenation was measured using functional near infrared spectroscopy (fNIRS). Results: There were no significant differences between the three groups on the subscales of the multitasking stressor. In addition, there were no significant differences on self-report measures of perceived workload (NASA Task Load Index). In terms of mood, ecstasy users were significantly less calm and less relaxed compared with drug-naive controls. There were also significant differences at three voxels on the fNIRS, indicating decreased blood oxygenation in ecstasy users compared with drug-naive controls at voxel 2 (left dorsolateral prefrontal cortex), voxel 14 and voxel 16 (right dorsolateral prefrontal cortex), and compared with polydrug controls at V14. Conclusions: The results of the present study provide support for changes in brain activation during performance of demanding tasks in ecstasy polydrug users, which could be related to cerebral vasoconstriction.

32. Singh et al. (2014). Mapping cortical haemodynamics during neonatal seizures using diffuse optical tomography: A case study

Abstract: Seizures in the newborn brain represent a major challenge to neonatal medicine. Neonatal seizures are poorly classified, under-diagnosed, difficult to treat and are associated with poor neurodevelopmental outcome. Video-EEG is the current gold-standard approach for seizure detection and monitoring. Interpreting neonatal EEG requires expertise and the impact of seizures on the developing brain remains poorly understood. In this case study we present the first ever images of the haemodynamic impact of seizures on the human infant brain, obtained using simultaneous diffuse optical tomography (DOT) and video-EEG with whole-scalp coverage. Seven discrete periods of ictal electrophysiological activity were observed during a 60 minute recording of an infant with hypoxic–ischaemic encephalopathy. The resulting DOT images show a remarkably consistent, high-amplitude, biphasic pattern of changes in cortical blood volume and oxygenation in response to each electrographic event. While there is spatial variation across the cortex, the dominant haemodynamic response to seizure activity consists of an initial increase in cortical blood volume prior to a large and extended decrease typically lasting several minutes. This case study demonstrates the wealth of physiologically and clinically relevant information that DOT–EEG techniques can yield. The consistency and scale of the haemodynamic responses observed here also suggest that DOT–EEG has the potential to provide improved detection of neonatal seizures.

33. Ariturk et al. (2014). Utility of Cerebral Oxymetry for Assessing Cerebral Arteriolar Carbon Dioxide Reactivity during Cardiopulmonary Bypass

Abstract: Background: Our study evaluated changes in cerebral arterial oxygen saturation (rSO2) during cardiopulmonary bypass (CPB) that were caused by changes in arterial carbon dioxide tension (PaCO2). Methods: A group of 126 patients undergoing routine, elective, first-time coronary artery bypass graft surgery (CABG) was entered into a prospective study using bilateral near-infrared spectroscopy (NIRS) before anesthetic induction (T1), after anesthetic induction (T2), and continuing at 5-minute intervals during moderate hypothermic (32°C) CPB. Pump flows were set at 2.5 L/min/m2 and adjusted to maintain mean arterial pressure (MAP) within 10 mmHg of the MAP recorded at the initial fifth minute of CPB (T3). Thirty-two patients were excluded from data collection because MAP could not be stabilized within the target range of 60-90 mmHg. In the remaining 94 patients, after obtaining steady state flow, MAP, and oxygenation, a trial period of hypocarbia (mean PaCO2 of 30 mmHg) was induced by increasing oxygenator fresh gas flow rate (FGFR) to 2.5 L/min/m2 (T4). A reciprocal period was then measured at reduced FGFR (0.75 L/min/m2) (T5). Results: After 20 minutes of a higher (2.75 L/min/m2) (FGFR), mean PaCO2 decreased from a baseline of 38 ± 4 mmHg to 30 ± 2 mmHg. This was associated with a parallel decrease (-10±9%) in mixed cerebral oxygen saturation without alteration of mean
arterial oxygen tension (PaO2), lactate, MAP, CPB flow, or other parameters implying increased cerebral oxygen extraction. Conclusion: Parallel changes in PaCO2 and rSO2 occur during CPB when other variables remain constant, and are due to the effects of carbon dioxide on cerebral arterioles. Cerebral oxygen saturation measured by NIRS may be a useful indirect measure of PaCO2 when continuous blood gas analysis is not possible during open-heart surgery. Cerebral oximetry values may be useful measurements for setting an optimum gas flow rate through the oxygenator.

34. Cem et al. (2014). **Efficacy of Near-Infrared Spectrometry for Monitoring the Cerebral Effects of Severe Dilutional Anemia**

**Abstract:** Introduction: Clear guidelines for red cell transfusion during cardiac surgery have not yet been established. The current focus on blood conservation during cardiac surgery has increased the urgency to determine the minimum safe hematocrit for these patients. The aim of this study was to determine whether monitoring of cerebral regional oxygen saturation (rSO2) via near-infrared spectrometry (NIRS) is effective for assessing the cerebral effects of severe dilutional anemia during elective coronary arterial bypass graft surgery (CABG). Methods: The prospective observational study involved patients who underwent cerebral rSO2 monitoring by NIRS during elective isolated first-time CABG: an anemic group (N=15) (minimum Hemoglobin (Hb) <7 g/dL at any period during cardiopulmonary bypass (CPB) and a control group (N=15) (Hb >8 g/dL during CPB). Mean arterial pressure (MAP), pump blood flow, blood lactate level, pCO2, pO2 at five time points and cross-clamp time, extracorporeal circulation time were recorded for each patient. Group results statistically were compared. Results: The anemic group had significantly lower mean preoperative Hb than the control group (10.3 mg/dL versus 14.2 mg/dL; P = .001). The lowest Hb levels were observed in the hypothermic period of CPB in the anemic group. None of the controls exhibited a >20% decrease in cerebral rSO2. Eleven (73.3%) of the anemic patients required an increase in pump blood flow to raise their cerebral rSO2. Conclusions: In this study, the changes in cerebral rSO2 in the patients with low Hb were within acceptable limits, and this was in concordance with the blood lactate levels and blood-gas analysis. It can be suggested that NIRS monitoring of cerebral rSO2 can assist in decision making related to blood transfusion and dilutional anemia during CPB.

35. Kopton et al. (2014). **Near-infrared spectroscopy (NIRS) as a new tool for neuroeconomic research**

**Abstract:** Over the last decade, the application of neuroscience to economic research has gained in importance and the number of neuroeconomic studies has grown extensively. The most common method for these investigations is fMRI. However, fMRI has limitations (particularly concerning situational factors) that should be countered with other methods. This review elaborates on the use of functional Near-Infrared Spectroscopy (fNIRS) as a new and promising tool for investigating economic decision making both in field experiments and outside the laboratory. We describe results of studies investigating the reliability of prototype NIRS studies, as well as detailing experiments using conventional and stationary fNIRS devices to analyze this potential. This review article shows that further research using mobile fNIRS for studies on economic decision making outside the laboratory could be a fruitful avenue helping to develop the potential of a new method for field experiments outside the laboratory.

36. Lee et al. (2014). **Comparison of two devices using near-infrared spectroscopy for the measurement of tissue oxygenation during a vascular occlusion test in healthy volunteers (INVOS® vs. InSpectra™)**

**Abstract:** The aim of this study was to compare tissue oxygen saturation as measured by INVOS® and InSpectra™ during a vascular occlusion test (VOT) in the same subject. Twenty healthy adults were investigated. The INVOS® and InSpectra™ probes were placed randomly on the right and left thenar eminence.
in the same participant and monitoring of tissue oxygen saturation (SrO2 from INVOS® and StO2 from InSpectra™) were begun. Pneumatic cuffs placed around each upper arm were inflated simultaneously to 30 mmHg above the initial systolic blood pressure and maintained until the tissue oxygen saturation had decreased to 40 % or below. The cuff pressure was then released rapidly. The time to achieve initial stability, the baseline value, the time from the baseline value to 40 %, the rate of deoxygenation, the rate of reoxygenation, and the hyperemic area under the curve were calculated from SrO2 and StO2. The baseline value by INVOS® was lower than that by InSpectra™ (75.6 ± 8.2 vs. 81.8 ± 3.4 %, p < 0.01). The time to reach stable baseline value was significantly longer for SrO2 than for StO2 (249 ± 86 and 54 ± 40 s respectively; p < 0.01). SrO2 declined to 40 % more rapidly than did the StO2 (147 ± 38 vs. 199 ± 41 s, p < 0.01). The deoxygenation and reoxygenation rates were higher (p < 0.01) and the reactive hyperemic area was more extensive for INVOS® than for InSpectra™ (p = 0.015). In conclusion, the VOT on the thenar muscle using INVOS® was as clinically applicable as InSpectra™, but baseline values and dynamic changes of INVOS® differed from those of InSpectra™.

37. Chuang et al. (2014). **Gender-related effects of prefrontal cortex connectivity: a resting-state functional optical tomography study**

**Abstract:** The prefrontal cortex (PFC) is thought to play an important role in “higher” brain functions such as personality and emotion that may associated with several gender-related mental disorders. In this study, the gender effects of functional connectivity, cortical lateralization and significantly differences in the PFC were investigated by using resting-state functional optical tomography (fOT) measurement. A total of forty subjects including twenty healthy male and twenty healthy female adults were recruited for this study. In the results, the hemoglobin responses are higher in the male group. Additionally, male group exhibited the stronger connectivity in the PFC regions. In the result of lateralization, leftward dominant was observed in the male group but bilateral dominance in the female group. Finally, the 11 channels of the inferior PFC regions (corresponding to the region of Brodmann area 45) are significant different with spectrum analysis. Our findings suggest that the resting-state fOT method can provide high potential to apply to clinical neuroscience for several gender-related mental disorders diagnosis.

38. Richards et al. (2014). **Blood pressure and cerebral blood flow oscillations: Friend or foe?**

**Abstract:** Variability in arterial pressure and cerebral blood flow has traditionally been interpreted as a marker of cardiovascular decompensation, and has been associated with negative clinical outcomes across varying time scales, from impending orthostatic syncope to an increased risk of stroke. Emerging evidence, however, suggests that increased hemodynamic variability may, in fact, be protective in the face of acute challenges to perfusion, including significant central hypovolemia and hypotension (including hemorrhage), and during cardiac bypass surgery. We present the dichotomous views on the role of hemodynamic variability on clinical outcome, including the physiological mechanisms underlying these patterns, and the potential impact of increased and decreased variability on cerebral perfusion and oxygenation. We suggest that reconciliation of these two apparently discrepant views may lie in the time scale of hemodynamic variability; short time scale variability appears to be cerebroprotective, while mid to longer term fluctuations are associated with primary and secondary end-organ dysfunction.


**Abstract:** Multiple sclerosis (MS) impairs brain activity through demyelination and loss of axons. Increased brain activity is accompanied by increases in microvascular hemoglobin oxygen saturation (oxygenation) and total hemoglobin, which can be measured using functional near-infrared spectroscopy (fNIRS). Due to the potentially reduced size and integrity of the white matter tracts within the corpus callosum, it may be expected
that MS patients have reduced functional communication between the left and right sides of the brain; this could potentially be an indicator of disease progression. To assess interhemispheric communication in MS, we used fNIRS during a unilateral motor task and the resting state. The magnitude of the change in hemoglobin parameters in the motor cortex was significantly reduced in MS patients during the motor task relative to healthy control subjects. There was also a significant decrease in interhemispheric communication between the motor cortices (expressed as coherence) in MS patients compared to controls during the motor task, but not during the resting state. fNIRS assessment of interhemispheric coherence during task execution may be a useful marker in disorders with white matter damage or axonal loss, including MS.

40. Uemura et al. (2014). Depressive symptoms in older adults are associated with decreased cerebral oxygenation of the prefrontal cortex during a trail-making test

Abstract: Growing evidence supports the relationships between depressive symptoms, cognitive decline, and brain structural changes in older adults. The purpose of this study was to determine whether depressive symptoms are related to cerebral oxygenation during cognitive tasks in older adults. In this study, 80 elderly subjects (73.9 ± 5.4 years, 34 males) were evaluated using multi-channel Near-infrared spectroscopy. Concentration changes (mmol cm/l) in oxy-hemoglobin (oxy-Hb), as the most reliable available indicator of changes in regional cerebral blood flow, in the right and left prefrontal cortex were measured during the Trail Making Test Part B (TMT-B). Depressive symptoms were assessed using the short Geriatric Depression Scale (GDS). Subjects were divided into a depressive group (GDS greater than or equal to 6) and non-depressive group (GDS lower than 6). In results, Oxy-Hb activation during the TMT-B was significantly smaller in the depressive group (n = 13) than in the non-depressive group (n = 67) in both the right and left prefrontal cortex. In the multivariate analysis, GDS scores were significantly negatively correlated with oxy-Hb activation after adjusting for age, gender and educational history (right, β = −0.32, p = 0.002; left, β = −0.25, p = 0.02). Less prefrontal activation in older adults with depressive symptoms may account for decline in executive function. Further studies are needed to investigate the influence of the less brain activation associated with depressive symptoms on future cognitive decline and structural brain changes in older adults.

41. Goodwin et al. (2014). Short-channel functional near-infrared spectroscopy regressions improve when source-detector separation is reduced

Abstract: In functional near-infrared spectroscopy (fNIRS) of human cerebral hemodynamics, dedicated surface-sensitive recording channels are useful for regressing out background hemodynamics and isolating activation-specific responses. A wide variety of source-detector separations have been utilized for this purpose. Here, we report a direct comparison of regression performance between two extremes of the reported range, 13 and 6 mm. Measurements of visual stimulation response (flickering radial checkerboard) were obtained from nine adults using a standard commercial source-detector grid with 13-mm diagonals, into which three extra detector fibers were placed to provide 6-mm channels at certain locations. When the NIRS recordings (17 total trials) were processed, the contrast-to-noise ratio was significantly higher with 6-mm regression channels than with 13 mm. The advantage could be due in part to the undesired sensing of brain activity by the 13-mm channels. We suggest that shorter distances be considered for optimal removal of superficial hemodynamics in NIRS signals from the adult brain.

42. Martelli et al. (2014). Phantoms for diffuse optical imaging based on totally absorbing objects, part 2: experimental implementation

Abstract: We present the experimental implementation and validation of a phantom for diffuse optical imaging based on totally absorbing objects for which, in the previous paper [J. Biomed. Opt.18(6), 066014, (2013)], we have provided the basic theory. Totally absorbing objects have been manufactured as black polyvinyl chloride
(PVC) cylinders and the phantom is a water dilution of intralipid-20% as the diffusive medium and India ink as the absorber, filled into a black scattering cell made of PVC. By means of time-domain measurements and of Monte Carlo simulations, we have shown the reliability, the accuracy, and the robustness of such a phantom in mimicking typical absorbing perturbations of diffuse optical imaging. In particular, we show that such a phantom can be used to generate any absorption perturbation by changing the volume and position of the totally absorbing inclusion.

43. Yamanaka et al. (2014). **Effect of Parietal Transcranial Magnetic Stimulation on Spatial Working Memory in Healthy Elderly Persons - Comparison of Near Infrared Spectroscopy for Young and Elderly**

**Abstract:** In a previous study, we succeeded in improving the spatial working memory (WM) performance in healthy young persons by applying transcranial magnetic stimulation (TMS) to the parietal cortex and simultaneously measuring the oxygenated hemoglobin (oxy-Hb) level using near-infrared spectroscopy (NIRS). Since an improvement in WM was observed when TMS was applied to the right parietal cortex, the oxy-Hb distribution seemed to support a model of hemispheric asymmetry (HA). In the present study, we used the same study design to evaluate healthy elderly persons and investigated the effect of TMS on WM performance in the elderly, comparing the results with those previously obtained from young persons. The application of TMS did not affect WM performance (both reaction time and accuracy) of 38 elderly participants (mean age = 72.5 years old). To investigate the reason for this result, we conducted a three-way ANOVA examining oxy-Hb in both young and elderly participants. For the right parietal TMS site in the elderly, TMS significantly decreased the oxy-Hb level during WM performance; this result was the opposite of that observed in young participants. An additional three-way ANOVA was conducted for each of the 52 channels, and a P value distribution map was created. The P value maps for the young participants showed a clearly localized TMS effect for both the WM and control task, whereas the P map for the elderly participants showed less significant channels and localization. Further analysis following the time course revealed that right-side parietal TMS had almost no effect on the frontal cortex in the elderly participants. This result can most likely be explained by age-related differences in HA arising from the over-recruitment of oxy-Hb, differentiation in the parietal cortex, and age-related alterations of the frontal-parietal networks.

44. Fudickar et al. (2014). **Effect of ischemic and pharmacological preconditioning of lower limb muscle tissue on tissue oxygenation measured by near-infrared spectroscopy – a pilot study**

**Abstract:** Background: Ischemic or volatile anesthetic preconditioning is defined as tissue protection from impending ischemic cell damage by repetitive short periods of tissue exposure to ischemia or volatile anesthetics. Objective of this study was to elucidate, if ischemic preconditioning and pharmacological preconditioning with sevoflurane have effects on muscle tissue oxygen saturation in patients undergoing surgical revascularization of the lower limb. Methods: In this prospective randomized pilot study ischemic and pharmacological (sevoflurane) preconditioning was performed in 40 patients with lower limb arterial occlusive disease undergoing surgical revascularization. Sevoflurane preconditioning was performed in one group (N = 20) by repetitive application of sevoflurane for six minutes interspersed by six minutes of washout. Thereafter, ischemic preconditioning was performed in all patients (N = 40) by repetitive clamping of the femoral artery for six minutes interspersed by six minutes of reperfusion. The effect of both procedures on leg muscle tissue oxygen saturation (rSO2) was measured by near-infrared spectroscopy during both procedures and during surgery and reperfusion (INVOS® 5100C Oxymeter with Small Adult SomaSensor® SAFB-SM, Somanetics, Troy, Michigan, USA). Results: Repetitive clamping and reperfusion of the femoral artery resulted in significant cyclic decrease and increase of muscle rSO2 (p < 0.0001). Pharmacological preconditioning with sevoflurane resulted in a faster and higher increase of rSO2 during postoperative reperfusion (Maximal 111% baseline ± 20 versus 103% baseline ± 14, p = 0.008) consistent with an additional effect of pharmacological preconditioning on leg perfusion. Conclusions:
Ischemic preconditioning of lower limb muscle tissue and pharmacological preconditioning with sevoflurane have an effect on tissue oxygenation in patients with lower limb occlusive arterial disease.


**Abstract:** A number of recent studies have demonstrated that near-infrared spectroscopy (NIRS) is a promising neuroimaging modality for brain-computer interfaces (BCIs). So far, most NIRS-based BCI studies have focused on enhancing the accuracy of the classification of different mental tasks. In the present study, we evaluated the performances of a variety of mental task combinations in order to determine the mental task pairs that are best suited for customized NIRS-based BCIs. To this end, we recorded event-related hemodynamic responses while seven participants performed eight different mental tasks. Classification accuracies were then estimated for all possible pairs of the eight mental tasks (C82=28). Based on this analysis, mental task combinations with relatively high classification accuracies frequently included the following three mental tasks: “mental multiplication,” “mental rotation,” and “right-hand motor imagery.” Specifically, mental task combinations consisting of two of these three mental tasks showed the highest mean classification accuracies. It is expected that our results will be a useful reference to reduce the time needed for preliminary tests when discovering individual-specific mental task combinations.

46. Bogler et al. (2014). Decoding Vigilance with NIRS

**Abstract:** Sustained, long-term cognitive workload is associated with variations and decrements in performance. Such fluctuations in vigilance can be a risk factor especially during dangerous attention demanding activities. Functional MRI studies have shown that attentional performance is correlated with BOLD-signals, especially in parietal and prefrontal cortical regions. An interesting question is whether these BOLD-signals could be measured in real-world scenarios, say to warn in a dangerous workplace whenever a subject's vigilance is low. Because fMRI lacks the mobility needed for such applications, we tested whether the monitoring of vigilance might be possible using Near-Infrared Spectroscopy (NIRS). NIRS is a highly mobile technique that measures hemodynamics in the surface of the brain. We demonstrate that non-invasive NIRS signals correlate with vigilance. These signals carry enough information to decode subjects' reaction times at a single trial level.

47. Salazar et al. (2014). Relationship between intraoperative regional cerebral oxygen saturation trends and cognitive decline after total knee replacement: a post-hoc analysis

**Abstract:** Background: Bilateral regional brain oxygen saturation (rSO2) trends, reflecting intraoperative brain oxygen imbalance, could warn of brain dysfunction. Various types of cognitive impairment, such as memory decline, alterations in executive function or subjective complaints, have been described three months after surgery. Our aim was to explore the potential utility of rSO2 values as a warning sign for the development of different types of decline in postoperative psychological function. Methods: Observational post-hoc analysis of data for the patient sample (n = 125) of a previously conducted clinical trial in patients over the age of 65 years undergoing total knee replacement under spinal anesthesia. Demographic, hemodynamic and bilateral rSO2 intraoperative values were recorded. An absolute rSO2 value of <50% or a reduction of >20% or >25% below baseline were chosen as relevant cutoffs. Composite function test scores were created from baseline to three months for each patient and adjusted for the mean (SD) score changes for a control group (n = 55). Tests were used to assess visual-motor coordination and executive function (VM-EF) (Wechsler Digit Symbol-Coding and Visual Reproduction, Trail Making Test) and memory (Auditory Verbal Learning, Wechsler Memory Scale); scales were used to assess psychological symptoms. Results: We observed no differences in baseline rSO2 values; rSO2 decreased significantly in all patients during surgery (P < 0.0001). Seventy-five patients (60%) had no sign of cognitive decline or psychological symptoms. Twenty-one patients (16.8%) had memory decline, 3 (2.4%) had
VM-EF decline, and 33 (26.4%) had psychological symptoms. Left and right rSO2 values were asymmetric in patients who had memory decline (mean [SD] left-right ratio of 95.03 [8.51] vs 101.29 [6.7] for patients with no changes, P = 0.0012). The mean right-left difference in rSO2 was also significant in these patients (-2.87% [4.73%], lower on the right, P = 0.0034). Conclusions: Detection of a trend to asymmetry in rSO2 values can warn of possible postoperative onset of memory decline. Psychological symptoms and memory decline were common three months after knee replacement in our patients over the age of 65 years.

48. Chen et al. (2014). **Diffuse optical tomography enhanced by clustered sparsity for functional brain imaging**

**Abstract:** Diffuse optical tomography (DOT) is a noninvasive technique which measures hemodynamic changes in the tissue with near infrared light, which has been increasingly used to study brain functions. Due to the nature of light propagation in the tissue, the reconstruction problem is severely ill-posed. For linearized DOT problems, sparsity regularization has achieved promising results over conventional Tikhonov regularization in recent experimental research. As extensions to standard sparsity, it is widely known that structured sparsity based methods are often superior in terms of reconstruction accuracy, when the data follows some structures. In this paper, we exploit the structured sparsity of diffuse optical images. Based on the functional specialization of the brain, it is observed that the in vivo absorption changes caused by a specific brain function would be clustered in certain region(s) and not randomly distributed. Thus, a new algorithm is proposed for this clustered sparsity reconstruction (CSR). Results of numerical simulations and phantom experiments have demonstrated the superiority of the proposed method over the state-of-the-art methods. An example from human in vivo measurements further confirmed the advantages of the proposed CSR method.

49. Beijer et al. (2014). **Microcirculation of skeletal muscle adapts differently to a resistive exercise intervention with and without superimposed whole-body vibrations**

**Abstract:** Whole-body vibration (WBV) training is commonly practiced and may enhance peripheral blood flow. Here, we investigated muscle morphology and acute microcirculatory responses before and after a 6-week resistive exercise training intervention without (RE) or with (RVE) simultaneous whole-body vibrations (20 Hz, 6 mm peak-to-peak amplitude) in 26 healthy men in a randomized, controlled parallel-design study. Total haemoglobin (tHb) and tissue oxygenation index (TOI) were measured in gastrocnemius muscle (GM) with near-infrared spectroscopy (NIRS). Whole-body oxygen consumption (VO2) was measured via spirometry, and skeletal muscle morphology was determined in soleus (SOL) muscle biopsies. Our data reveal that exercise-induced muscle deoxygenation both before and after 6 weeks training was similar in RE and RVE (P = 0.76), although VO2 was 20% higher in the RVE group (P<0.001). The RVE group showed a 14%-point increase in reactive hyperaemia (P = 0.007) and a 27% increase in blood volume (P<0.01) in GM after 6 weeks of training. The number of capillaries around fibres was increased by 15% after 6 weeks training in both groups (P<0.001) with no specific effect of superimposed WBV (P = 0.61). Neither of the training regimens induced fibre hypertrophy in SOL. The present findings suggest an increased blood volume and vasodilator response in GM as an adaptation to long-term RVE, which was not observed after RE alone. We conclude that RVE training enhances vasodilation of small arterioles and possibly capillaries. This effect might be advantageous for muscle thermoregulation and the delivery of oxygen and nutrients to exercising muscle and removal of carbon dioxide and metabolites.

50. Kovelman et al. (2014). **Words in the bilingual brain: an fNIRS brain imaging investigation of lexical processing in sign-speech bimodal bilinguals**

**Abstract:** Early bilingual exposure, especially exposure to two languages in different modalities such as speech and sign, can profoundly affect an individual's language, culture, and cognition. Here we explore the hypothesis that bimodal dual language exposure can also affect the brain's organization for language. These changes occur
across brain regions universally important for language and parietal regions especially critical for sign language (Newman et al., 2002). We investigated three groups of participants (N = 29) that completed a word repetition task in American Sign Language (ASL) during fNIRS brain imaging. Those groups were (1) hearing ASL-English bimodal bilinguals (n = 5), (2) deaf ASL signers (n = 7), and (3) English monolinguals naïve to sign language (n = 17). The key finding of the present study is that bimodal bilinguals showed reduced activation in left parietal regions relative to deaf ASL signers when asked to use only ASL. In contrast, this group of bimodal signers showed greater activation in left temporo-parietal regions relative to English monolinguals when asked to switch between their two languages (Kovelman et al., 2009). Converging evidence now suggest that bimodal bilingual experience changes the brain bases of language, including the left temporo-parietal regions known to be critical for sign language processing (Emmorey et al., 2007). The results provide insight into the resilience and constraints of neural plasticity for language and bilingualism.

51. Fujimaki et al. (2014). Association between Sub-Threshold Affective Symptoms and Prefrontal Activation in Non-Clinical Population—An NIRS Study

Abstract: Only a few studies have examined the relationship between self-assessment of affective symptoms and brain activation in a non-clinical population. The aim of the present study was to assess this relationship and examine the underlying cortical mechanisms in a non-clinical population. Seventy-nine healthy male volunteers were assessed for affective symptoms using the Zung Self-rating Depression Scale (SDS), for apathy using the Apathy Scale (AS), and for feelings of stress using the Stress Arousal Checklist (SACL). Participants also performed a serial arithmetic task according to the Uchida-Kraepelin performance test while hemoglobin concentration changes were assessed on the surface of the prefrontal cortex (PFC) using 32-channel near-infrared spectroscopy (NIRS). The activity on the right side of PFC had a significant negative correlation with the SDS score. The AS and SACL scores were positively correlated with the SDS score. Furthermore, in a multiple regression analysis, SDS scores were predicted by the activity of the right PFC, AS scores, and SACL scores. These results suggest that the association between the cortical activation changes, apathy, and feelings of stress may objectively identify individuals with sub-threshold affective symptoms.

52. Prabhakar et al. (2014). Current concepts of optimal cerebral perfusion pressure in traumatic brain injury

Abstract: Traumatic brain injury (TBI) consists of varied pathophysiological consequences and alteration of intracranial dynamics, reduction of the cerebral blood flow and oxygenation. In the past decade more emphasis has been directed towards optimizing cerebral perfusion pressure (CPP) in patients who have suffered TBI. Injured brain may show signs of ischemia if CPP remains below 50 mmHg and raising the CPP above 60 mmHg may avoid cerebral oxygen desaturation. Though CPP above 70 mmHg is influential in achieving an improved patient outcome, maintenance of CPP higher than 70 mmHg was associated with greater risk of acute respiratory distress syndrome (ARDS). The target CPP has been laid within 50-70 mmHg. Cerebral blood flow and metabolism are heterogeneous after TBI and with regional temporal differences in the requirement for CPP. Brain monitoring techniques such as jugular venous oximetry, monitoring of brain tissue oxygen tension (PbrO2), and cerebral microdialysis provide complementary and specific information that permits the selection of the optimal CPP. This review highlights the rationale for use CPP directed therapies and neuromonitoring to identify optimal CPP of head injured patients. The article also reviews the evidence provided by various clinical trials regarding optimal CPP and their application in the management of head injured patients.
53. Chalak et al. (2014). The “neurovascular unit approach” to evaluate mechanisms of dysfunctional autoregulation in asphyxiated newborns in the era of hypothermia therapy

Abstract: Despite improvements in obstetrical and neonatal care, and introduction of hypothermia as a neuroprotective therapy, perinatal brain injury remains a frequent cause of cerebral palsy, mental retardation and epilepsy. The recognition of dysfunction of cerebral autoregulation is essential for a real time measure of efficacy to identify those who are at highest risk for brain injury. This article will focus on the “neurovascular unit” approach to the care of asphyxiated neonates and will address 1) potential mechanisms of dysfunctional cerebral blood flow (CBF) regulation, 2) optimal monitoring methodology such as NIRS (near infrared spectroscopy), and TCD (transcutaneous Doppler), and 3) clinical implications of monitoring in the neonatal intensive care setting in asphyxiated newborns undergoing hypothermia and rewarming. Critical knowledge of the functional regulation of the neurovascular unit may lead to improved ability to predict outcomes in real time during hypothermia, as well as differentiate non-responders who might benefit from additional therapies.

54. Schaeffner et al. (2014). An fNIRS investigation of associative recognition in the prefrontal cortex with a rapid event-related design

Abstract: Background: Functional near-infrared spectroscopy (fNIRS) measures hemodynamic changes at the cortical level. The use of fNIRS is growing in popularity for studying cognitive neuroscience in which event-related designs are widely used with functional magnetic resonance imaging (fMRI). However, the applicability of event-related designs with fNIRS has not been fully understood. Therefore, the present study employed fNIRS with a rapid-presentation event-related design for investigating prefrontal cortical activity during complex associative recognition. New method: Participants studied a list of word pairs and were later given an associative recognition test. Throughout the experiment, each event was presented rapidly (~4 s). Data were sorted based on accuracy of associative memory judgments and analyzed using the general linear model (GLM) with an event-related design. Results: During retrieval, significant increases in oxygenated hemoglobin concentrations were observed in dorsolateral and ventrolateral prefrontal regions for successful associative recognition. When comparing retrieval to encoding, significant increases in oxygenated hemoglobin concentrations were also observed in dorsolateral prefrontal cortex. Comparison with existing method: The current fNIRS results corroborate previous fMRI findings that have demonstrated the involvement of dorsolateral and ventrolateral prefrontal cortex in associative recognition. Therefore, the present study validates versatile use of fNIRS with a rapid-presentation event-related design in the investigation of neural mechanisms of associative memory. Conclusion: The findings of this study provide evidence that fNIRS can be a viable research method for investigating complex cognitive processes commonly of interest in cognitive neuroscience. Taken together, these results demonstrate that fNIRS can be a cost-effective and accessible experimental tool for cognitive neuroscience.

55. Igarashi et al. (2014). Effects of stimulation by three-dimensional natural images on prefrontal cortex and autonomic nerve activity: a comparison with stimulation using two-dimensional images

Abstract: Empirical evidence suggests that three-dimensional (3D) images of nature promote physiological relaxation in humans by providing more realistic effects compared with two-dimensional (2D) images. However, no studies have evaluated the physiological relaxation effects of nature-derived 3D images on prefrontal cortex and autonomic nerve activity. The present study aimed to clarify the physiological relaxation effects of visual stimulation by 3D flower images on prefrontal cortex and autonomic nerve activity. Nineteen male university students (22.2±0.6 years) were presented with 3D and 2D images of the water lily for 90 s. Prefrontal cortex activity was measured using near-infrared spectroscopy, while autonomic nerve activity was measured using heart rate variability (HRV). Psychological effects were determined using a modified semantic differential method (SD). Compared with visual stimulation by 2D images, that by 3D images resulted in a significant
decrease in oxyhemoglobin concentration in the right prefrontal cortex, lower sympathetic activity as calculated by the ratio of the low-frequency to high-frequency HRV component, and a significantly greater realistic feeling as evidenced by higher SD ratings. In conclusion, visual stimulation by realistic 3D floral images promotes physiological relaxation more effectively than the corresponding 2D image.

56. Gervain (2014). Near-infrared spectroscopy: recent advances in infant speech perception and language acquisition research

- no Abstract available –

57. Lee et al. (2014). Feasibility of near-infrared spectroscopic tomography for intraoperative functional cerebral monitoring: A primate study

Abstract: Objective: The wide-ranging manipulations to the cardiovascular system that frequently occur during cardiac surgery can expose the brain to variations in its blood supply that could prove deleterious. As a first step to developing a resource suitable for monitoring such changes, we detected the hemodynamic events induced in the brain of a primate model, using high-density near-infrared spectroscopy combined with tomographic reconstruction methods and validated the findings using established radiologic and histologic techniques.

Methods: Continuous monitoring of the relative changes in the components of the cerebral hemoglobin signal was performed using high-density near-infrared spectroscopy (270 source-detector channel array) in anesthetized bonnet macaques with the brain exposed to induced ischemia and other acute events. A comparative analysis (exact binomial test) applied to reconstructed 3-dimensional images before and after the events and between cerebral hemispheres, combined with postprocedure magnetic resonance imaging, and postmortem histopathologic examination of the macaques' brains was performed to document and validate the spatial features revealed by the optical findings.

Results: Relative changes in the measured and calculated components of the hemoglobin signal, in response to the performed manipulations, revealed substantial concurrence among the reconstructed 3-dimensional images, magnetic resonance imaging of the macaques' brains, and postmortem histopathologic examination findings. Concurrence was seen when the manipulated hemoglobin concentration and associated oxygenation levels were either increased or decreased, and whether they were bilateral or restricted to a specified hemisphere. Conclusions: Continuous near-infrared spectroscopy tomography has been shown to accurately capture and localize cerebral ischemia, vasodilatation, and hemorrhage in primates in real time. These findings are directly applicable to clinical intraoperative functional cerebral monitoring.

58. Gunadi et al. (2014). Spatial sensitivity and penetration depth of three cerebral oxygenation monitors

Abstract: The spatial sensitivities of NIRO-100, ISS Oximeter and TRS-20 cerebral oxygenation monitors are mapped using the local perturbation method to inform on their penetration depths and susceptibilities to superficial contaminations. The results show that TRS-20 has the deepest mean penetration depth and is less sensitive than the other monitors to a localized absorption change in the superficial layer. However, an integration time of more than five seconds is required by the TRS-20 to achieve an acceptable level of signal-to-noise ratio, which is the poorest amongst the monitors. With the exception of NIRO-100 continuous wave method, the monitors are not significantly responsive to layer-wide absorption change that occurs in the superficial layer.
59. Sekiguchi et al. (2014). **Pial arteries respond earlier than penetrating arterioles to neural activation in the somatosensory cortex in awake mice exposed to chronic hypoxia: an additional mechanism to proximal integration signaling?**

**Abstract:** The pial and penetrating arteries have a crucial role in regulating cerebral blood flow (CBF) to meet neural demand in the cortex. Here, we examined the longitudinal effects of chronic hypoxia on the arterial diameter responses to single whisker stimulation in the awake mouse cortex, where activity-induced responses of CBF were gradually attenuated. The vasodilation responses to whisker stimulation under prehypoxia normal conditions were 8.1% and 12% relative to their baselines in the pial arteries and penetrating arterioles, respectively. After 3 weeks of hypoxia, however, these responses were significantly reduced to 5.5% and 4.1%, respectively. The CBF response, measured using laser-Doppler flowmetry (LDF), induced by the same whisker stimulation was also attenuated (14% to 2.6%). A close linear correlation was found for the responses between the penetrating arteriolar diameter and LDF, and their temporal dynamics. After 3 weeks of chronic hypoxia, the initiation of vasodilation in the penetrating arterioles was significantly extended, but the pial artery responses remained unchanged. These results show that vasodilation of the penetrating arterioles followed the pial artery responses, which are not explainable in terms of proximal integration signaling. The findings therefore indicate an additional mechanism for triggering pial artery dilation in the neurovascular coupling.

60. Mintzer et al. (2014). **Monitoring regional tissue oxygen extraction in neonates <1250 g helps identify transfusion thresholds independent of hematocrit**

**Abstract:** OBJECTIVE: We sought to characterize the effects of “booster” packed red blood cell transfusions on multisite regional oxygen saturation in very low birth weight neonates during the first postnatal week and to examine the utility of fractional tissue oxygen extraction as an estimate of tissue oxygenation adequacy. STUDY DESIGN: Data were collected in an observational near-infrared spectroscopy (NIRS) pilot survey of 500–1250 g neonates during the first postnatal week. A before-after analysis of “booster” transfusions, defined as empiric 15 mL/kg transfusion following 10 mL/kg cumulative phlebotomy losses, was conducted upon cardiopulmonary, laboratory, and spectroscopy data. RESULT: Ten neonates (gestational age 26 ± 0 wk; birth weight 879 ± 49 g) received 14 transfusions at 3 ± 0 postnatal days. Mean hematocrit increased from 35.2 ± 1.2 to 38.5 ± 1.2 % (P < 0.05) following transfusion; pH, base deficit, lactate, creatinine, and cardiopulmonary parameters were unchanged. Cerebral, renal, and splanchnic tissue oxygenation increased 10, 18, and 16%, with concomitant decreases in calculated oxygen extraction of 27, 30, and 9% (all P < 0.05), consistent with enhanced tissue oxygenation. These findings were not observed in a non-transfused comparison group of nine patients. CONCLUSION: “Booster” transfusions improved indices of regional tissue oxygenation while no departures were observed in conventional cardiovascular assessments. We speculate that NIRS-derived oxygenation parameters can provide an objective, graded, and continuous estimate of oxygen delivery-consumption balance not evident using standard monitoring techniques.

61. Chen et al. (2014). **A noninvasive brain computer interface using visually-induced near-infrared spectroscopy responses**

**Abstract:** Visually-induced near-infrared spectroscopy (NIRS) response was utilized to design a brain computer interface (BCI) system. Four circular checkerboards driven by distinct flickering sequences were displayed on a LCD screen as visual stimuli to induce subjects’ NIRS responses. Each flickering sequence was a concatenated sequence of alternative flickering segments and resting segments. The flickering segment was designed with fixed duration of 3 s whereas the resting segment was chosen randomly within 15–20 s to create the mutual independencies among different flickering sequences. Six subjects were recruited in this study and subjects were requested to gaze at the four visual stimuli one-after-one in a random order. Since visual responses in human brain are time-locked to the onsets of visual stimuli and the flicker sequences of distinct visual stimuli were designed mutually independent, the NIRS responses induced by user’s gazed targets can be discerned from non-
gazed targets by applying a simple averaging process. The accuracies for the six subjects were higher than 90% after 10 or more epochs being averaged.

62. Meng et al. (2014). **Cerebral oximetry: Three questions to ask**

**Abstract:** Cerebral oximetry based on near-infrared spectroscopy can non-invasively measure hemoglobin oxygen saturation in mixed arterial, venous and capillary blood in the brain. In order to determine if this is a clinically desirable monitor, we need to answer three questions in order. The first question is if cerebral oximetry monitors an important aspect of physiology. The second question is if the physiology can be optimized based on this monitor. The third question is if the outcome can be improved based on cerebral oximetry-guided clinical care. In this review, we share our answers to these three questions.

63. Sorensen et al. (2014). **Ventilatory strategy during liver transplantation: implications for near-infrared spectroscopy-determined frontal lobe oxygenation**

**Abstract:** BACKGROUND: As measured by near infrared spectroscopy (NIRS), cerebral oxygenation (ScO2) may be reduced by hyperventilation in the anhepatic phase of liver transplantation surgery (LTx). Conversely, the brain may be subjected to hyperperfusion during reperfusion of the grafted liver. We investigated the relationship between ScO2 and end-tidal CO2 tension (EtCO2) during the various phases of LTx.

**METHODS:** In this retrospective study, 49 patients undergoing LTx were studied. Forehead ScO2, EtCO2, minute ventilation (VE), and hemodynamic variables were recorded from the beginning of surgery through to the anhepatic and reperfusion phases during LTx.

**RESULTS:** In the anhepatic phase, ScO2 was reduced by 4.3% (95% confidence interval: 2.5-6.0%; P < 0.0001), EtCO2 by 0.3 kPa (0.2-0.4 kPa; P < 0.0001), and VE by 0.4 L/min (0.1-0.7 L/min; P = 0.0018). Conversely, during reperfusion of the donated liver, ScO2 increased by 5.5% (3.8-7.3%), EtCO2 by 0.7 kPa (0.5-0.8 kPa), and VE by 0.6 L/min (0.3-0.9 L/min; all P < 0.0001). Changes in ScO2 were correlated to those in EtCO2 (Pearson r = 0.74; P < 0.0001). CONCLUSION: During LTx, changes in ScO2 are closely correlated to those of EtCO2. Thus, this retrospective analysis suggests that attention to maintain a targeted EtCO2 would result in a more stable ScO2 during the operation.

64. Fabiani et al. (2014). **Taking the pulse of aging: Mapping pulse pressure and elasticity in cerebral arteries with optical methods**

**Abstract:** Cerebrovascular support is crucial for healthy cognitive and brain aging. Arterial stiffening is a cause of reduced brain blood flow, a predictor of cognitive decline, and a risk factor for cerebrovascular accidents and Alzheimer's disease. Arterial health is influenced by lifestyle factors, such as cardiorespiratory fitness (CRF). We investigated new noninvasive optical measures of cerebrovascular health, which provide estimates of arterial pulse parameters (pulse pressure, transit time, and compliance/elasticity) within specific cerebral arteries and cortical regions, and low-resolution maps of large superficial cerebral arteries. We studied naturally occurring variability in these parameters in adults (aged 55–87), and found that these indices of cerebrovascular health are negatively correlated with age and positively with CRF and gray and white matter volumes. Further, regional pulse transit time predicts specific neuropsychological performance.


**Abstract:** This paper presents a methodology for online estimation of brain activities with reduction in the effects of physiological noises in functional near-infrared spectroscopy signals. The input–output characteristics of a hemodynamic response are modeled as an autoregressive moving average model together with exogenous
physical signals (i.e., ARMAX). In contrast to the fixed design matrix in the conventional general linear model, the proposed model incorporates the temporal variations in the experimental paradigm as well as in the hemodynamics. The performance of the proposed method has been tested by using box-car type functions followed by individual tapping tasks. The results and their significance were verified using t-statistics indicating that ARMAX seems to be better able to track/reveal the hemodynamic response. Also, online brain-activation maps were generated for localizing brain activities. Experimental results are compared with those of the existing conventional GLM-based method.


Abstract: An increasing number of functional near-infrared spectroscopy (fNIRS) studies utilize a general linear model (GLM) approach, which serves as a standard statistical method for functional magnetic resonance imaging (fMRI) data analysis. While fMRI solely measures the blood oxygen level dependent (BOLD) signal, fNIRS measures the changes of oxy-hemoglobin (oxy-Hb) and deoxy-hemoglobin (deoxy-Hb) signals at a temporal resolution severalfold higher. This suggests the necessity of adjusting the temporal parameters of a GLM for fNIRS signals. Thus, we devised a GLM-based method utilizing an adaptive hemodynamic response function (HRF). We sought the optimum temporal parameters to best explain the observed time series data during verbal fluency and naming tasks. The peak delay of the HRF was systematically changed to achieve the best-fit model for the observed oxy- and deoxy-Hb time series data. The optimized peak delay showed different values for each Hb signal and task. When the optimized peak delays were adopted, the deoxy-Hb data yielded comparable activations with similar statistical power and spatial patterns to oxy-Hb data. The adaptive HRF method could suitably explain the behaviors of both Hb parameters during tasks with the different cognitive loads during a time course, and thus would serve as an objective method to fully utilize the temporal structures of all fNIRS data.

67. Chaddad et al. (2014). Low-Noise Front-End Receiver Dedicated to Biomedical Devices: NIRS Acquisition System

Abstract: This paper concerns the design and the implementation of a fully integrated front-end intended to Near-Infrared Spectroscopy System (NIRS) acquisition system. A low-noise transimpedance amplification (TIA) circuit followed by adjustable cut-off frequency and a low-pass filter (LPF) was implemented in order to decrease noise circuit of NIRS detectors. For TIA, a single ended common source, common gate input stage based on a cascode structure is used to get a higher gain-bandwidth closed-loop transimpedance amplifier. To enhance the circuit noise performance, a single feedback transistor technique is used, compared to passive feedback, to achieved high quality data from NIRS acquisition channel. The proposed LPF combines two control methods to adjust the low cut-off frequency. Simulation results show a TIA gain of 104.2 dBΩ, ?3dB bandwidth of 19 MHz and an equivalent input noise current spectral density of 446 fA/√Hz. LPF filter exhibits a relatively constant noise 201nV/√Hz from 0 Hz to 700 KHz and linearity performance over its entire tuning range. The proposed front-end of NIRS preamplifier is implemented using 0.18 pm CMOS technology.

68. Selb et al. (2014). Sensitivity of near-infrared spectroscopy and diffuse correlation spectroscopy to brain hemodynamics: simulations and experimental findings during hypercapnia

Abstract: Near-infrared spectroscopy (NIRS) and diffuse correlation spectroscopy (DCS) are two diffuse optical technologies for brain imaging that are sensitive to changes in hemoglobin concentrations and blood flow, respectively. Measurements for both modalities are acquired on the scalp, and therefore hemodynamic processes in the extracerebral vasculature confound the interpretation of cortical hemodynamic signals. The sensitivity of NIRS to the brain versus the extracerebral tissue and the contrast-to-noise ratio (CNR) of NIRS to cerebral
hemodynamic responses have been well characterized, but the same has not been evaluated for DCS. This is important to assess in order to understand their relative capabilities in measuring cerebral physiological changes. We present Monte Carlo simulations on a head model that demonstrate that the relative brain-to-scalp sensitivity is about three times higher for DCS (0.3 at 3 cm) than for NIRS (0.1 at 3 cm). However, because DCS has higher levels of noise due to photon-counting detection, the CNR is similar for both modalities in response to a physiologically realistic simulation of brain activation. Even so, we also observed higher CNR of the hemodynamic response during graded hypercapnia in adult subjects with DCS than with NIRS.

69. Han et al. (2014). Wavelet coherence analysis of prefrontal tissue oxyhaemoglobin signals as measured using near-infrared spectroscopy in elderly subjects with cerebral infarction

**Abstract:** This study aims to assess the prefrontal functional connectivity using wavelet coherence analysis of cerebral tissue oxyhaemoglobin concentration (Delta [HbO2]) signals in elderly subjects with cerebral infarction (CI) during the resting state. Continuous recordings of near-infrared spectroscopy (NIRS) signals were obtained from the left and right prefrontal lobes in 10 subjects with CI (age: 74.4 ± 9.0 years) and 18 healthy elderly subjects (age: 69.9 ± 7.3 years) during the resting state. The coherence between left and right prefrontal Delta [HbO2] oscillations in four frequency intervals (I, 0.6–2 Hz; II, 0.145–0.6 Hz; III, 0.052–0.145 Hz and IV, 0.021–0.052 Hz) was analyzed using wavelet coherence analysis. In healthy elderly subjects, the Delta [HbO2] oscillations were significantly wavelet coherent in intervals I and III (p < 0.05), wavelet phase coherent in intervals from I to IV. In elderly subjects with CI, the left and right Delta [HbO2] oscillations were significantly wavelet coherent and phase coherent in interval I (p < 0.05). In elderly subjects with CI, the power and phase coherences were significantly lower in interval III (p < 0.01) than in healthy subjects. The difference in wavelet coherence between the healthy elderly and elderly with CI indicates an altered brain functional connectivity in CI patients. This may be useful for assessing the effectiveness of functional recovery following a CI.

70. Clark et al. (2014). Enhanced Somatosensory Feedback Reduces Prefrontal Cortical Activity During Walking in Older Adults

**Abstract:** Background. The coordination of steady state walking is relatively automatic in healthy humans, such that active attention to the details of task execution and performance (controlled processing) is low. Somatosensation is a crucial input to the spinal and brainstem circuits that facilitate this automaticity. Impaired somatosensation in older adults may reduce automaticity and increase controlled processing, thereby contributing to deficits in walking function. The primary objective of this study was to determine if enhancing somatosensory feedback can reduce controlled processing during walking, as assessed by prefrontal cortical activation. Methods. Fourteen older adults (age 77.1±5.56 years) with mild mobility deficits and mild somatosensory deficits participated in this study. Functional near-infrared spectroscopy was used to quantify metabolic activity (tissue oxygenation index, TOI) in the prefrontal cortex. Prefrontal activity and gait spatiotemporal data were measured during treadmill walking and overground walking while participants wore normal shoes and under two conditions of enhanced somatosensation: wearing textured insoles and no shoes. Results. Relative to walking with normal shoes, textured insoles yielded a bilateral reduction of prefrontal cortical activity for treadmill walking (ΔTOI = −0.85 and −1.19 for left and right hemispheres, respectively) and for overground walking (ΔTOI = −0.51 and −0.66 for left and right hemispheres, respectively). Relative to walking with normal shoes, no shoes yielded lower prefrontal cortical activity for treadmill walking (ΔTOI = −0.69 and −1.13 for left and right hemispheres, respectively), but not overground walking. Conclusions. Enhanced somatosensation reduces prefrontal activity during walking in older adults. This suggests a less intensive utilization of controlled processing during walking.

71. Yuan et al. (2014). A systematic investigation of reflectance diffuse optical tomography using nonlinear reconstruction methods and continuous wave measurements
Abstract: We conducted a systematic investigation of the reflectance diffuse optical tomography using continuous wave (CW) measurements and nonlinear reconstruction algorithms. We illustrated and suggested how to fine-tune the nonlinear reconstruction methods in order to optimize target localization with depth-adaptive regularizations, reduce boundary noises in the reconstructed images using a logarithm based objective function, improve reconstruction quantification using transport models, and resolve crosstalk problems between absorption and scattering contrasts with the CW reflectance measurements. The upgraded nonlinear reconstruction algorithms were evaluated with a series of numerical and experimental tests, which show the potentials of the proposed approaches for imaging both absorption and scattering contrasts in the deep targets with enhanced image quality.


Abstract: Object: The authors undertook this study to investigate whether the physiological mechanism of cerebral blood flow (CBF) regulation by alteration of the arterial partial pressure of carbon dioxide (PaCO2) can be used to increase CBF after aneurysmal subarachnoid hemorrhage (aSAH). Methods: In 6 mechanically ventilated patients with poor-grade aSAH, the PaCO2 was first decreased to 30 mm Hg by modification of the respiratory rate, then gradually increased to 40, 50 and 60 mm Hg for 15 minutes each setting. Thereafter, the respirator settings were returned to baseline parameters. Intracerebral CBF measurement and brain tissue oxygen saturation (StiO2), measured by near-infrared spectroscopy (NIRS), were the primary and secondary end points. Intracranial pressure (ICP) was controlled by external ventricular drainage. Results: A total of 60 interventions were performed in 6 patients. CBF decreased to 77% of baseline at a PaCO2 of 30 mm Hg and increased to 98%, 124%, and 143% at PaCO2 values of 40, 50, and 60 mm Hg, respectively. Simultaneously, StiO2 decreased to 94%, then increased to 99%, 105%, and 111% of baseline. A slightly elevated delivery rate of cerebrospinal fluid was noticed under continuous drainage. ICP remained constant. After returning to baseline respirator settings, both CBF and StiO2 remained elevated and only gradually returned to pre-hypercapnia values without a rebound effect. None of the patients developed secondary cerebral infarction. Conclusions: Gradual hypercapnia was well tolerated by poor-grade SAH patients. Both CBF and StiO2 reacted with a sustained elevation upon hypercapnia; this elevation outlasted the period of hypercapnia and only slowly returned to normal without a rebound effect. Elevations of ICP were well compensated by continuous CSF drainage. Hypercapnia may yield a therapeutic potential in this state of critical brain perfusion.

73. Izzetoglu et al. (2014). UAV Operators Workload Assessment by Optical Brain Imaging Technology (fNIR)

Abstract: The use of unmanned aerial vehicles (UAVs) is expected to increase exponentially over the next few years. UAV ground operators are required to acquire skills quickly and completely, with a level of expertise that builds the operator's confidence in his/her ability to control the UAV under adverse conditions. As UAVs are held to increasingly higher standards of efficiency and safety, operators are routinely required to perform more informationally dense and cognitively demanding tasks, resulting in increased cognitive workloads during operation. Functional brain monitoring offers the potential to help UAV operators meet these challenges. Recent research has demonstrated the utility of near-infrared-based functional brain imaging systems (fNIRS) for the purpose of monitoring frontal cortical areas that support executive functions (attention, working memory, response monitoring). This technology provides portable, safe, affordable, noninvasive, and minimally intrusive monitoring systems with rapid application times for continuous measures of cortical activity. fNIR technology allows continuous monitoring of operators during training as they develop expertise, as well as the capacity to monitor their cognitive workload under operational conditions while controlling UAVs in critical missions. This chapter discusses the utilization of fNIR in the monitoring of a cognitive workload during UAV operation, and as an objective measure of expertise development, that is, the transition from novice to expert during operator training.
74. Ding et al. (2014). **Neural correlates of own- and other-race face recognition in preschoolers: A functional near-infrared spectroscopy (fNIRS) study**

Abstract: Previous studies revealed a neural other-race effect (NORE) paralleling the behavioral other-race effect, suggesting that adults asymmetrical experience with own- and other-race faces have a direct impact not only on their behavior but also on neural responses. However, the developmental origin of the neural other-race effect is still unknown. The present study used the functional Near-infrared Spectroscopy (fNIRS) methodology to investigate the neural correlates of preschoolers own- and other-race face processing. An old-new paradigm was used to assess preschoolers recognition ability of own- and other-race faces (N=67, Age: 4.08 to 6.50 Years). FNIRS data revealed that own-race faces elicited significantly greater [oxy-Hb] changes than other-race faces in the left middle frontal gyrus (left MFG, BA10, 46) and the left middle occipital gyrus (left MOG, V2). The [oxy-Hb] activity differences between own- and other-race faces, or the NORE was significantly positively correlated with age in the left MFG, but negatively correlated with age in the left MOG. Moreover, these areas had strong functional connectivity with a large swath of the cortical regions in terms of the NORE. These results taken together suggest that similar to school aged children and adults, preschoolers devote different amounts of neural resources to processing own- and other-race faces. But the size of their neural other-race effect and associated functional regional connectivity undergo developmental changes.

75. Hill et al. (2014). **Greater Oxygenation of Prefrontal Cortex During Information-Integration (vs. Rule-Based) Category Learning**

Abstract: The COVIS theory of categorization (Ashby et al 1998, Psychological Review) posits that verbalizable (explicit) rule learning is mediated in part by prefrontal cortex (PFC), while nonverbalizable (implicit) rule learning is mediated chiefly by basal ganglia structures. COVIS also predicts that both learning systems attempt to determine each category response on each trial (i.e., the systems compete). On this basis, we predicted unique patterns of PFC blood flow depending on how participants performed on perceptual category learning tasks that required either selective attention to a single stimulus dimension ("rule-based" learning) or attention to multiple stimulus dimensions at once ("information-integration" learning). Participants completed rule-based and information-integration category learning tasks with two-dimensional stimuli (gabor patches varying in orientation and spatial frequency across trials). Hemodynamic response was measured in dorsolateral PFC using functional Near Infrared Spectroscopy (fNIRS). As expected, we found similar levels of oxygenated hemoglobin (Hbo2) in DLPFC early in learning for both conditions, and a divergence of activity level across tasks over the series of training blocks. This divergence was mediated by the type of rule used in each task. Participants using the incorrect rule type (a 1-dimensional rule) during information integration learning showed higher PFC activity than those using the appropriate rule type. These results support COVIS and suggest that these perceptual category learning tasks provide a dissociation that may be useful for examining changes in PFC integrity due to injury or aging.

76. Zhang et al. (2014). **Predominant endothelial vasomotor activity during human sleep: a near-infrared spectroscopy study**

Abstract: Vasomotion is important in the study of vascular disorders, including stroke. Spontaneous low and very low hemodynamic oscillations (3–150 mHz) measured with near-infrared spectroscopy (NIRS) reflect the endothelial (3–20 mHz), neurogenic (20–40 mHz) and myogenic (40–150 mHz) components of vasomotion. We investigated sleep-specific patterns of vasomotion by characterizing hemodynamic oscillations with NIRS in healthy subjects, and tested the feasibility of NIRS as a bedside tool for monitoring vasomotion during whole-night sleep. To characterize local cerebral vasomotion, we compared cerebral NIRS measurements with muscular NIRS measurements and peripheral arterial oxygen saturation (SpO2) during different sleep stages in 14 healthy volunteers. Spectral powers of hemodynamic oscillations in the frequency range of endothelial vasomotion were systemically predominant in every sleep stage, and the powers of endothelial and neurogenic
vasomotion decreased in deep sleep as compared with light sleep and rapid eye movement (REM) sleep in brain, muscle, and SpO2. The decrease in the powers of myogenic vasomotion in deep sleep only occurred in brain, and not in muscle. These results point to a predominant role of endothelial function in regulating vasomotion during sleep. The decline in cerebral endothelial and neurogenic vasomotion during progression to deeper non-REM sleep suggests that deep sleep may play a protective role for vascular function. NIRS can be used to monitor endothelial control of vasomotion during nocturnal sleep, thus providing a promising non-invasive bedside tool with which to study the sleep-relevant pathological mechanisms in vascular diseases and stroke.

77. Perry et al. (2014). Cerebral hemodynamics during graded Valsalva maneuvers

Abstract: The Valsalva maneuver (VM) produces large and abrupt changes in mean arterial pressure (MAP) that challenge cerebral blood flow and oxygenation. We examined the effect of VM intensity on middle cerebral artery blood velocity (MCAv) and cortical oxygenation responses during (phases I–III) and following (phase IV) a VM. Healthy participants (n = 20 mean ± SD: 27 ± 7 years) completed 30 and 90% of their maximal VM mouth pressure for 10 s (order randomized) whilst standing. Beat-to-beat MCAv, cerebral oxygenation (NIRS) and MAP across the different phases of the VM are reported as the difference from standing baseline. There were significant interaction (phase * intensity) effects for MCAv, total oxygenation index (TOI) and MAP (all P < 0.01). MCAv decreased during phases II and III (P < 0.01), with the greatest decrease during phase III (−5 ± 8 and −19 ± 15 cm s−1 for 30 and 90% VM, respectively). This pattern was also evident in TOI (phase III: −1 ± 1 and −5 ± 4%, both P < 0.05). Phase IV increased MCAv (22 ± 15 and 34 ± 23 cm s−1), MAP (15 ± 14 and 24 ± 17 mm Hg) and TOI (5 ± 6 and 7 ± 5%) relative to baseline (all P < 0.05). Cerebral autoregulation, indexed, as the %MCAv/%MAP ratio, showed a phase effect only (P < 0.001), with the least regulation during phase IV (2.4 ± 3.0 and 3.2 ± 2.9). These data illustrate that an intense VM profoundly affects cerebral hemodynamics, with a reactive hyperemia occurring during phase IV following modest ischemia during phases II and III.

78. Shah et al. (2014). A model-free approach to increasing the effect size of FNIRS data

Abstract: Localizing brain activity in noisy functional near-infrared spectroscopy (fNIRS) data plays an important role when investigating task-related hemodynamics of the neuronal sites. We present a novel method for capturing drifts in the fNIRS data which increases the effect size of interest of the oxygenated (HbO) and deoxygenated (HbR) hemoglobin responses. Using linear least-squares, a consistent hemodynamic response function (HRF) of the fNIRS HbO/HbR response is estimated as a first-step that leads to an optimal estimate of the drift based on a wavelet thresholding technique. The de-drifted fNIRS responses are then obtained by removing the estimated drifts from the fNIRS time-series. Its performance is assessed using both simulated data and a real fNIRS data set obtained from a finger tapping task. The application results reveal that the proposed model-free method performs optimal de-drifting and increases the effect size of the fNIRS data.

79. Tekes et al. (2014). Apparent Diffusion Coefficient Scalars Correlate with Near-Infrared Spectroscopy Markers of Cerebrovascular Autoregulation in Neonates Cooled for Perinatal Hypoxic-Ischemic Injury

Abstract: BACKGROUND AND PURPOSE: Neurologic morbidity remains high in neonates with perinatal hypoxic-ischemic injury despite therapeutic hypothermia. DTI provides qualitative and quantitative information about the microstructure of the brain, and a near-infrared spectroscopy index can assess cerebrovascular autoregulation. We hypothesized that lower ADC values would correlate with worse autoregulatory function.

MATERIALS AND METHODS: Thirty-one neonates with hypoxic-ischemic injury were enrolled. ADC scalars were measured in 27 neonates (age range, 4-15 days) in the anterior and posterior centrum semiovale, basal ganglia, thalamus, posterior limb of the internal capsule, pons, and middle cerebellar peduncle on MRI obtained after completion of therapeutic hypothermia. The blood pressure range of each neonate with the most robust
autoregulation was identified by using a near-infrared spectroscopy index. Autoregulatory function was measured by blood pressure deviation below the range with optimal autoregulation.

RESULTS: In neonates who had MRI on day of life ≥10, lower ADC scalars in the posterior centrum semiovale ($r = -0.87$, $P = .003$, $n = 9$) and the posterior limb of the internal capsule ($r = -0.68$, $P = .04$, $n = 9$) correlated with blood pressure deviation below the range with optimal autoregulation during hypothermia. Lower ADC scalars in the basal ganglia correlated with worse autoregulation during rewarming ($r = -0.71$, $P = .05$, $n = 8$).

CONCLUSIONS: Blood pressure deviation from the optimal autoregulatory range may be an early biomarker of injury in the posterior centrum semiovale, posterior limb of the internal capsule, and basal ganglia. Optimizing blood pressure to support autoregulation may decrease the risk of brain injury in cooled neonates with hypoxic-ischemic injury.

80. Barker et al. (2014). An evaluation of the normal range of StO2 measurements at rest and following a mixed exercise protocol

Abstract: Background: Assessment of local tissue oxygenation (StO2) using near infrared spectroscopy is an emerging technique in medical practice with applications in trauma/sepsis management, diagnosis of acute compartment syndrome and assessment of tissue viability. Despite this, there have been little published data on the range of StO2 values in normal subjects. Methods: StO2 measurements were recorded in 105 infantry soldiers using an INVOS System Monitor (Somanetics) from both deltoids, the anterior compartment of the leg and the frontal lobe of the brain. Measurements were taken at rest and following completion of a mixed exercise protocol, consisting of overarm pull-ups, sit-ups and a 3-mile run. Results: StO2 values at rest were found to have a wide normal range with a skew left distribution. Mean StO2 was similar between the deltoids (left deltoid 80%, right deltoid 79%), but significantly different between other anatomical sites (leg 68%, brain 73%). However, all sites demonstrated a similar lower range cut-off at approximately 40%. Following exercise, there was a significant increase in StO2 values at all sites (left deltoid by 3.1±2.0%, right deltoid by 2.6±2.3%, leg by 8.0±2.3% and brain by 8.6±1.9%), which persisted for at least 10 min. Conclusions: There were statistically significant differences in mean StO2 values recorded at different anatomical sites, although the reference ranges were wide and substantially overlapped. StO2 increased at all sites after exercise with the effect persisting for at least 10 min. The interaction between exercise and pathological phenomena remains unknown and is an area for further study.

81. Hayashida et al. (2014). Estimated cerebral oxyhemoglobin as a useful indicator of neuroprotection in patients with post-cardiac arrest syndrome: a prospective, multicenter observational study

Abstract: INTRODUCTION: Little is known about oxyhemoglobin (oxy-Hb) levels in the cerebral tissue during the development of anoxic and ischemic brain injury. We hypothesized that the estimated cerebral oxy-Hb level, a product of Hb and regional cerebral oxygen saturation (rSO2), determined at hospital arrival may reflect the level of neuroprotection in patients with post-cardiac arrest syndrome (PCAS).

METHODS: The Japan Prediction of neurological Outcomes in patients with Post cardiac arrest (J-POP) registry is a prospective, multicenter, cohort study to test whether rSO2 predicts neurological outcomes after out-of-hospital cardiac arrest (OHCA). This study assessed a subgroup of consecutive patients who fulfilled the J-POP registry criteria and successfully achieved return of spontaneous circulation (ROSC) from OHCA. The primary outcome measure was the neurological status at 90 days.

RESULTS: We analyzed data from 495 consecutive comatose survivors who were successfully resuscitated from OHCA, including 119 comatose patients with prehospital return of spontaneous circulation (ROSC; 24.0%) and 376 cardiac arrests at hospital arrival. In total, 75 patients (15.1%) presented with good neurological outcomes. Univariate analysis revealed that the cerebral oxy-Hb levels were significantly higher in patients with good outcomes. Multivariate logistic regression using the backward elimination method confirmed that the oxy-Hb level was a significant predictor of good neurological outcomes (adjusted odds ratio: 1.27, 95% confidence interval
(CI): 1.11 to 1.46). Analysis of the area under the receiver operating characteristic curve (AUC) revealed that an oxy-Hb cut-off of 5.5 provided optimal sensitivity and specificity for predicting good neurological outcomes (AUC: 0.87, 95% CI: 0.83 to 0.91; sensitivity: 77.3%; specificity: 85.6%). The oxy-Hb level appeared to be an excellent prognostic indicator with significant advantages over rSO2 and base excess according to AUC analysis. The significant trend for good neurological outcomes was consistent, even in the subgroup of patients who achieved return of spontaneous circulation upon hospital arrival (1st quartile: 0%; 2nd quartile: 16.7%; 3rd quartile: 29.4%; 4th quartile: 53.3%, P <0.05).

CONCLUSIONS: The cerebral oxy-Hb level may predict neurological outcomes and is a simple and excellent indicator of neuroprotection in patients with PCAS.

82. Moreno et al. (2014). **Intercostal and forearm muscle deoxygenation during respiratory fatigue in patients with heart failure: potential role of a respiratory muscle metaboreflex**

**Abstract:** The purpose of this study was to determine the effect of respiratory muscle fatigue on intercostal and forearm muscle perfusion and oxygenation in patients with heart failure. Five clinically stable heart failure patients with respiratory muscle weakness (age, 66±12 years; left ventricle ejection fraction, 34±3%) and nine matched healthy controls underwent a respiratory muscle fatigue protocol, breathing against a fixed resistance at 60% of their maximal inspiratory pressure for as long as they could sustain the predetermined inspiratory pressure. Intercostal and forearm muscle blood volume and oxygenation were continuously monitored by near-infrared spectroscopy with transducers placed on the seventh left intercostal space and the left forearm. Data were compared by two-way ANOVA and Bonferroni correction. Respiratory fatigue occurred at 5.1±1.3 min in heart failure patients and at 9.3±1.4 min in controls (P<0.05), but perceived effort, changes in heart rate, and in systolic blood pressure were similar between groups (P>0.05). Respiratory fatigue in heart failure reduced intercostal and forearm muscle blood volume (P<0.05) along with decreased tissue oxygenation both in intercostal (heart failure, -2.6±1.6%; controls, +1.6±0.5%; P<0.05) and in forearm muscles (heart failure, -4.5±0.5%; controls, +0.5±0.8%; P<0.05). These results suggest that respiratory fatigue in patients with heart failure causes an oxygen demand/delivery mismatch in respiratory muscles, probably leading to a reflex reduction in peripheral limb muscle perfusion, featuring a respiratory metaboreflex.


**Abstract:** We present a novel lens-based broadband near-infrared spectroscopy system to simultaneously measure cerebral changes in tissue oxygenation and haemodynamics via estimation of the changes in haemoglobin concentration; in addition to oxygen utilization via the measurement of the oxidation state of cytochrome-c-oxidase (CCO). We demonstrate the use of the system in a cohort of 6 newborn infants with neonatal encephalopathy in the Neonatal Intensive Care Unit for continuous measurement periods of up to 5 days. NIRS data was collected from above the frontal lobe on the left and right hemispheres simultaneously with systemic data to allow multimodal data analysis. This allowed us to study the NIRS variables in response to global pathophysiological events and we focused our analysis to spontaneous oxygen desaturations. We identified changes from the NIRS variables during 236 oxygen desaturations from over 212 hours of data with a change from the baseline to nadir of -12 ± 3%. There was a consistent negative change in the Δ[HbD] (= oxygenated -deoxygenated haemoglobin) and Δ[oxCCO] measurements, mean decreases were 3.0 ± 1.7μM and 0.22 ± 0.11μM, and a positive change in the Δ[HbT] (= oxygenated + deoxygenated haemoglobin) measurements across all subjects, mean increase was 0.85 ± 0.58μM. We have shown with a feasibility study that the relationship between haemoglobin oxygenation changes and CCO oxidation changes during these desaturation events was significantly associated with a magnetic resonance spectroscopy (MRS)-measured biomarker of injury severity (r = 0.91, p<0.01).
84. Nishimura et al. (2014). **Dorsolateral prefrontal hemodynamic responses during a verbal fluency task in hypomanic bipolar disorder**

**Abstract:** Objectives: Neuroimaging studies have suggested prefrontal dysfunction in response to cognitive activation in bipolar disorder (BD). However, its characteristics in manic states have not been well understood. Thus, we compared prefrontal hemodynamic responses during a cognitive task between hypomanic and depressive states in BD. We then longitudinally compared hypomanic and subsequent euthymic states.

Methods: The prefrontal function of 27 patients with BD (11 hypomanic and 16 depressed) and 12 age- and gender-matched healthy controls (HCs) was evaluated using near-infrared spectroscopy (NIRS) during a verbal fluency task (VFT). Hypomanic symptoms were assessed using the Young Mania Rating Scale. Among the 11 hypomanic patients, eight participated in the second NIRS measurement after their hypomanic symptoms resolved.

Results: VFT performance did not differ among hypomanic, depressed, and HC groups. Both BD groups exhibited significantly lower activation during the VFT than HCs in the broader bilateral prefrontal cortex. Hemodynamic changes in the left dorsolateral prefrontal cortex (DLPFC) in the hypomanic patients with BD were significantly larger than those in the depressed patients. In addition, hypomanic symptom severity was positively correlated with activation in the left DLPFC and frontopolar cortex in patients with BD. Follow-up measurement of the hypomanic patients revealed that prefrontal activation was decreased after hypomanic symptoms resolved.

Conclusions: Combining cross-sectional and longitudinal assessments, the present results suggest that prefrontal hemodynamic responses associated with cognitive activation differ between hypomanic and depressive states in BD. NIRS measurement could be a useful tool for objectively evaluating state-dependent characteristics of prefrontal hemodynamics in BD.

85. Nishimura et al. (2014). **Coherent hemodynamics spectroscopy in a single step**

**Abstract:** Coherent Hemodynamics Spectroscopy (CHS) is a technique based on inducing cerebral hemodynamic oscillations at multiple frequencies, measuring them with near-infrared spectroscopy (NIRS), and analyzing them with a hemodynamic model to obtain physiological information such as blood transit times in the microvasculature and the autoregulation cutoff frequency. We have previously demonstrated that such oscillations can be induced one frequency at a time. Here we demonstrate that CHS can be performed by a single inflation of two pneumatic thigh cuffs (duration: 2 min; pressure: 200 mmHg), whose sudden release produces a step response in systemic arterial blood pressure that lasts for ~20 s and induces cerebral hemodynamics that contain all the frequency information necessary for CHS. Following a validation study on simulated data, we performed measurements on human subjects with this new method based on a single occlusion/release of the thigh cuffs and with the previous method based on sequential sets of cyclic inflation/deflation one frequency at a time, and demonstrated that the two methods yield the same CHS spectra and the same physiological parameters (within measurement errors). The advantages of the new method presented here are that CHS spectra cover the entire bandwidth of the induced hemodynamic response, they are measured over ~20 s thus better satisfying the requirement of time invariance of physiological conditions, and they can be measured every ~2.5 min thus achieving finer temporal sampling in monitoring applications.

86. Giacometti et al. (2014). **Correspondence of electroencephalography and near-infrared spectroscopy sensitivities to the cerebral cortex using a high-density layout**

**Abstract:** This study investigates the correspondence of the cortical sensitivity of electroencephalography (EEG) and near-infrared spectroscopy (NIRS). EEG forward model sensitivity to the cerebral cortex was calculated for 329 EEG electrodes following the 10-5 EEG positioning system using a segmented structural magnetic resonance imaging scan of a human subject. NIRS forward model sensitivity was calculated for the same subject using 156 NIRS source-detector pairs selected from 32 source and 32 detector optodes positioned on the scalp using a
subset of the 10-5 EEG positioning system. Sensitivity correlations between colocalized NIRS source-detector pair groups and EEG channels yielded $R=0.46\pm0.08$. Groups of NIRS source-detector pairs with maximum correlations to EEG electrode sensitivities are tabulated. The mean correlation between the point spread functions for EEG and NIRS regions of interest (ROI) was $R=0.43\pm0.07$. Spherical ROIs with radii of 26 mm yielded the maximum correlation between EEG and NIRS averaged across all cortical mesh nodes. These sensitivity correlations between EEG and NIRS should be taken into account when designing multimodal studies of neurovascular coupling and when using NIRS as a statistical prior for EEG source localization.

87. Funane et al. (2014). **Greater contribution of cerebral than extracerebral hemodynamics to near-infrared spectroscopy signals for functional activation and resting-state connectivity in infants**

Abstract: While near-infrared spectroscopy (NIRS) has been increasingly applied to neuroimaging and functional connectivity studies in infants, it has not been quantitatively examined as to what extent the deep tissue (such as cerebral tissue) as opposed to shallow tissue (such as scalp), contributes to NIRS signals measured in infants. A method for separating the effects of deep- and shallow-tissue layers was applied to data of nine sleeping three-month-old infants who had been exposed to 3-s speech sounds or silence (i.e., resting state) and whose hemodynamic changes over their bilateral temporal cortices had been measured by using an NIRS system with multiple source-detector (S-D) distances. The deep-layer contribution was found to be large during resting [67% at S-D 20 mm, 78% at S-D 30 mm for oxygenated hemoglobin (oxy-Hb)] as well as during the speech condition (72% at S-D 20 mm, 82% at S-D 30 mm for oxy-Hb). A left-right connectivity analysis showed that correlation coefficients between left and right channels did not differ between original- and deep-layer signals under no-stimulus conditions and that of original- and deep-layer signals were larger than those of the shallow layer. These results suggest that NIRS signals obtained in infants with appropriate S-D distances largely reflected cerebral hemodynamic changes.

88. Llysd-Fox et al. (2014). **Coregistering functional near-infrared spectroscopy with underlying cortical areas in infants**

Abstract: Functional near-infrared spectroscopy (fNIRS) is becoming a popular tool in developmental neuroscience for mapping functional localized brain responses. However, as it cannot provide information about underlying anatomy, researchers have begun to conduct spatial registration of fNIRS channels to cortical anatomy in adults. The current work investigated this issue with infants by coregistering fNIRS and magnetic resonance imaging (MRI) data from 55 individuals. Our findings suggest that fNIRS channels can be reliably registered with regions in the frontal and temporal cortex of infants from 4 to 7 months of age. Although some macro-anatomical regions are difficult to consistently define, others are more stable and fNIRS channels on an age-appropriate MRI template are often consistent with individual infant MRIs. We have generated a standardized scalp surface map of fNIRS channel locators to reliably locate cortical regions for fNIRS developmental researchers. This new map can be used to identify the inferior frontal gyrus, superior temporal sulcus (STS) region [which includes the superior and middle temporal gyri (MTG) nearest to the STS], and MTG and temporal-parietal regions in 4- to 7-month-old infants. Future work will model data for the whole head, taking into account the properties of light transport in tissue, and expanding to different ages across development.

89. Blasi et al. (2014). **Test–retest reliability of functional near infrared spectroscopy in infants**

Abstract: There has been a rapid rise in the number of publications using functional near infrared spectroscopy (fNIRS) for human developmental research over the past decade. However test–retest reliability of this measure of brain activation in infants remains unknown. To assess this, we utilized data from a longitudinal cohort who
participated in an fNIRS study on social perception at two age points. Thirteen infants had valid data from two sessions held 8.5 months apart (4 to 8 months and 12 to 16 months). Inter- and intrasession fNIRS test–retest reliability was assessed at the individual and group levels using the oxyhemoglobin (HbO2) signal. Infant compliance with the study was similar in both sessions (assessed by the proportion of time infants looked to the stimuli), and there was minimal discrepancy in sensor placement over the targeted area between sessions. At the group level, good spatial overlap of significant responses and signal reliability was seen (spatial overlap was 0.941 and average signal change within a region of interest was r=0.896). At participant level, spatial overlap was acceptable (>0.5 on average across infants) although signal reliability varied between participants. This first study of test–retest reliability of fNIRS in infants shows encouraging results, particularly for group-based analysis.

90. Oddo et al. (2014). Monitoring of Brain and Systemic Oxygenation in Neurocritical Care Patients

Abstract: Maintenance of adequate oxygenation is a mainstay of intensive care, however, recommendations on the safety, accuracy, and the potential clinical utility of invasive and non-invasive tools to monitor brain and systemic oxygenation in neurocritical care are lacking. A literature search was conducted for English language articles describing bedside brain and systemic oxygen monitoring in neurocritical care patients from 1980 to August 2013. Imaging techniques e.g., PET are not considered. A total of 281 studies were included, the majority described patients with traumatic brain injury (TBI). All tools for oxygen monitoring are safe. Parenchymal brain oxygen (PbtO2) monitoring is accurate to detect brain hypoxia, and it is recommended to titrate individual targets of cerebral perfusion pressure (CPP), ventilator parameters (PaCO2, PaO2), and transfusion, and to manage intracranial hypertension, in combination with ICP monitoring. SjvO2 is less accurate than PbtO2. Given limited data, NIRS is not recommended at present for adult patients who require neurocritical care. Systemic monitoring of oxygen (PaO2, SaO2, SpO2) and CO2 (PaCO2, end-tidal CO2) is recommended in patients who require neurocritical care.

91. Spyrou et al. (2014). Singular spectrum analysis as a preprocessing filtering step for fNIRS brain computer interfaces

Abstract: Near Infrared Spectroscopy is a method that measures the brain’s haemodynamic response. It is of interest in brain-computer interfaces where haemodynamic patterns in motor tasks are exploited to detect movement. However, the NIRS signal is usually corrupted with background biological processes, some of which are periodic or quasi-periodic in nature. Singular spectrum analysis (SSA) is a time-series decomposition method which separates a signal into a trend, oscillatory components and noise with minimal prior assumptions about their nature. Due to the frequency spectrum overlap of the movement response and of background processes such as Mayer waves, spectral filters are usually suboptimal. In this study, we perform SSA both in an online and a block fashion resulting in the removal of periodic components and in increased classification performance. Our study indicates that SSA is a practical method that can replace spectral filtering and is evaluated on healthy participants and patients with tetraplegia.

92. Habermehl et al. (2014). Optimizing the regularization for image reconstruction of cerebral diffuse optical tomography

Abstract: Functional near-infrared spectroscopy (fNIRS) is an optical method for noninvasively determining brain activation by estimating changes in the absorption of near-infrared light. Diffuse optical tomography (DOT) extends fNIRS by applying overlapping “high density” measurements, and thus providing a three-dimensional imaging with an improved spatial resolution. Reconstructing brain activation images with DOT requires solving an underdetermined inverse problem with far more unknowns in the volume than in the surface measurements. All methods of solving this type of inverse problem rely on regularization and the choice of
corresponding regularization or convergence criteria. While several regularization methods are available, it is unclear how well suited they are for cerebral functional DOT in a semi-infinite geometry. Furthermore, the regularization parameter is often chosen without an independent evaluation, and it may be tempting to choose the solution that matches a hypothesis and rejects the other. In this simulation study, we start out by demonstrating how the quality of cerebral DOT reconstructions is altered with the choice of the regularization parameter for different methods. To independently select the regularization parameter, we propose a cross-validation procedure which achieves a reconstruction quality close to the optimum. Additionally, we compare the outcome of seven different image reconstruction methods for cerebral functional DOT. The methods selected include reconstruction procedures that are already widely used for cerebral DOT [minimum ℓ2-norm estimate (ℓ2MNE) and truncated singular value decomposition], recently proposed sparse reconstruction algorithms [minimum ℓ1- and a smooth minimum ℓ0-norm estimate (ℓ1MNE, ℓ0MNE, respectively)] and a depth- and noise-weighted minimum norm (wMNE). Furthermore, we expand the range of algorithms for DOT by adapting two EEG-source localization algorithms [sparse basis field expansions and linearly constrained minimum variance (LCMV) beamforming]. Independent of the applied noise level, we find that the LCMV beamformer is best for single spot activations with perfect location and focality of the results, whereas the minimum ℓ1-norm estimate succeeds with multiple targets.


Abstract: The object of the current study is to explore the neural substrate for effects of atomoxetine (ATX) on inhibitory control in school-aged children with attention deficit hyperactivity disorder (ADHD) using functional near-infrared spectroscopy (fNIRS). We monitored the oxy-hemoglobin signal changes of sixteen ADHD children (6–14 years old) performing a go/no-go task before and 1.5 h after ATX or placebo administration, in a randomized, double-blind, placebo-controlled, crossover design. Sixteen age- and gender-matched normal controls without ATX administration were also monitored. In the control subjects, the go/no-go task recruited the right inferior and middle prefrontal gyri (IFG/MFG), and this activation was absent in pre-medicatet ADHD children. The reduction of right IFG/MFG activation was acutely normalized after ATX administration but not placebo administration in ADHD children. These results are reminiscent of the neuropharmacological effects of methylphenidate to up-regulate reduced right IFG/MFG function in ADHD children during inhibitory tasks. As with methylphenidate, activation in the IFG/MFG could serve as an objective neuro-functional biomarker to indicate the effects of ATX on inhibitory control in ADHD children. This promising technique will enhance early clinical diagnosis and treatment of ADHD in children, especially in those with a hyperactivity/impulsivity phenotype.

94. Rhondali et al. (2014). Sevoflurane anesthesia and brain perfusion

Abstract: Objective/Aim: To assess the impact of sevoflurane and anesthesia-induced hypotension on brain perfusion in children younger than 6 months. Background: Safe lower limit of blood pressure during anesthesia in infant is unclear, and inadequate anesthesia can lead to hypotension, hypocapnia, and low cerebral perfusion. Insufficient cerebral perfusion in infant during anesthesia is an important factor of neurological morbidity. In two previous studies, we assessed the impact of sevoflurane anesthesia on cerebral blood flow (CBF) by transcranial Doppler (TCD) and on brain oxygenation by NIRS, in children ≤2 years. As knowledge about consequences of anesthesia-induced hypotension on cerebral perfusion in children ≤6 months is scarce, we conducted a retrospective analysis to compare the data of CBF and brain oxygenation, in this specific population. Methods: We performed a retrospective analysis of data collected from our two previous studies. Baseline values of TCD or NIRS were recorded and then during sevoflurane anesthesia. From a database of 338 patients, we excluded all patients older than 6 months. Then, we compared physiological variables of TCD and NIRS population to ensure that the two groups were comparable. We compared rSO2c and TCD measurements
variation according to MAP value during sevoflurane anesthesia, using anova and Student–Newman–Keuls for posthoc analysis.

Results: One hundred and eighty patients were included in the analysis. TCD and NIRS groups were comparable. CBF velocities (CBFV) or rSO2c reflects a good cerebral perfusion when MAP is above 45 mmHg. When MAP is between 35 and 45 mmHg, CBFV variation reflects a reduction of CBF, but rSO2c increase is the consequence of a still positive balance between CMRO2 and O2 supply. Below 35 mmHg of MAP during anesthesia, CBFV decrease and rSO2c variation from baseline is low. For each category of MAP and for the two groups, etCo2 and expired fraction of sevoflurane (FeSevo) were comparable (anova P > 0.05).

Conclusion: In a healthy infant without dehydration, with normal PaCO2 and hemoglobin value, scheduled for short procedures, MAP is a good proxy of cerebral perfusion as we found that CBF assessed by CBFV and rSO2c decreased proportionally with cerebral perfusion pressure. During 1 MAC sevoflurane anesthesia, maintaining MAP beyond 35 mmHg during anesthesia is probably safe and sufficient. But when MAP decreases below 35 mmHg, CBF decreases and rSO2c variation from baseline is low despite CMRO2 reduction. In this situation, cerebral metabolic reserve is low and further changes of systemic conditions may be poorly tolerated by the brain.

95. Nakanishi et al. (2014). *Near-Infrared Spectroscopy during the Verbal Fluency Task before and after Treatment with Image Exposure and SSRI Therapy in Patients with Obsessive-Compulsive Disorder*

Abstract: Drug therapy with selective serotonin reuptake inhibitors (SSRIs) has been used as a treatment for obsessive-compulsive disorder (OCD). In the present case report, exposure therapy was used in addition to escitalopram (20 mg) to treat a 28-year-old female patient with OCD for 6 months. Her obsessive-compulsive symptoms comprised thoughts of words such as rape, crematorium, neck hanging, unhappy, death, die, and kill and images such as a shelf of gods, a shrine, a Buddhist altar, the sun, the sky, and the faces of her parents, siblings, and relatives. As exposure therapy, she was asked to view the images associated with these symptoms three times a day along with drug therapy. With the combination of drug and exposure therapies, her obsessive-compulsive symptoms improved within 6 months, with no interference in her daily life. Multichannel near-infrared spectroscopy (NIRS) showed improvement of brain function in the temporal and frontal lobes after treatment. These results suggest that NIRS can be used as an indicator of brain function improvement in patients with OCD.

96. Ri et al. (2014). *Theoretical prediction of the source-detector separation distance suited to the application of the spatially resolved spectroscopy from the near-infrared attenuation data cube of tissues*

Abstract: The modified Beer-Lambert law (MBL) and the spatially resolved spectroscopy are used to measure the tissue oxidation in muscles and brains by the continuous wave near-infrared spectroscopy. The spatially resolved spectroscopy predicts the change in the concentration of the absorber by measuring the slope of attenuation data according to the separation and calculating the absorption coefficients of tissue on the basis of the slope in attenuation at the separation distance satisfying the linearity of this slope. This study analyzed the appropriate source-detector separation distance by using the diffuse approximation resolution for photon migration when predicting the absorption coefficient by the spatially resolved spectroscopy on the basis of the reflective image of the tissue. We imagine the 3 dimensional attenuation image with the absorption coefficient, reduced scattering coefficient and separation distance as its axes and obtained the attenuation data cube by calculating the attenuation on a certain interval of coordinate on the basis of the diffuse approximation expression. We predicted the separation distance appropriate for the application of the spatially resolved spectroscopy by calculating and analyzing the first derivatives and second derivatives of attenuation with respect to the coordinates and also doing the differential pathlength factors and first derivatives of the attenuation with respect to the absorption coefficient from the attenuation data cube. When analyzing the
hemoglobin derivatives in tissues, the appropriate separation distances are 3-5cm and the value of its corresponding differential pathlength factors are from 3.5 to 5. These data agree with the preceding experimental data.

97. Khan et al. (2014). Decoding of four movement directions using hybrid NIRS-EEG brain-computer interface

Abstract: The hybrid brain-computer interface (BCI)'s multimodal technology enables precision brain-signal classification that can be used in the formulation of control commands. In the present study, an experimental hybrid near-infrared spectroscopy-electroencephalography (NIRS-EEG) technique was used to extract and decode four different types of brain signals. The NIRS setup was positioned over the prefrontal brain region, and the EEG over the left and right motor cortex regions. Twelve subjects participating in the experiment were shown four direction symbols, namely, “forward,” “backward,” “left,” and “right.” The control commands for forward and backward movement were estimated by performing arithmetic mental tasks related to oxy-hemoglobin (HbO) changes. The left and right directions commands were associated with right and left hand tapping, respectively. The high classification accuracies achieved showed that the four different control signals can be accurately estimated using the hybrid NIRS-EEG technology.

98. Khan et al. (2014). Cortical activation of passive hand movement using Haptic Knob: A preliminary multi-channel fNIRS study

Abstract: Several functional neuroimaging studies had been performed to explore the sensorimotor function for motor imagery and passive movement, but there is scanty work that investigated the cortical activation pattern for passive movement using functional Near-Infrared Spectroscopy (fNIRS). This study investigated the cortical activation pattern from fNIRS data of 8 healthy subjects performing motor imagery and passive movement tasks using a Haptic Knob robot. Group averaged contrasts were defined as motor imagery versus idle and passive movement versus idle. The cortical activations for motor imagery appeared on the contralateral sensorimotor area, whereas the cortical activations for passive movement appeared on both contralateral and ipsilateral sensorimotor area. This result suggests that the performance of passive movement has a wider cortical activation compared to the performance of motor imagery.

99. Quarto et al. (2014). Estimate of tissue composition in malignant and benign breast lesions by time-domain optical mammography

Abstract: The optical characterization of malignant and benign breast lesions is presented. Time-resolved transmittance measurements were performed in the 630-1060 nm range by means of a 7-wavelength optical mammograph, providing both imaging and spectroscopy information. A total of 62 lesions were analyzed, including 33 malignant and 29 benign lesions. The characterization of breast lesions was performed applying a perturbation model based on the high-order calculation of the pathlength of photons inside the lesion, which led to the assessment of oxy- and deoxy-hemoglobin, lipids, water and collagen concentrations. Significant variations between tumor and healthy tissue were observed in terms of both absorption properties and constituents concentration. In particular, benign lesions and tumors show a statistically significant discrimination in terms of absorption at several wavelengths and also in terms of oxy-hemoglobin and collagen content.
100. Chen et al. (2014). **A fast and high-sensitive dual-wavelength diffuse optical tomography system using digital lock-in photon-counting technique**

**Abstract:** We presented a novel dual-wavelength diffuse optical imaging system which can perform 2-D or 3-D imaging fast and high-sensitively for monitoring the dynamic change of optical parameters. A newly proposed lock-in photon-counting detection method was adopted for week optical signal collection, which brought in excellent property as well as simplified geometry. Fundamental principles of the lock-in photon-counting detection were elaborately demonstrated, and the feasibility was strictly verified by the linearity experiment. Systemic performance of the prototype set up was experimentally accessed, including stray light rejection and inherent interference. Results showed that the system possessed superior anti-interference capability (under 0.58% in darkroom) compared with traditional photon-counting detection, and the crosstalk between two wavelengths was lower than 2.28%. For comprehensive assessment, 2-D phantom experiments towards relatively large dimension model (diameter of 4cm) were conducted. Different absorption targets were imaged to investigate detection sensitivity. Reconstruction image under all conditions was exciting, with a desirable SNR. Study on image quality v.s. integration time put forward a new method for accessing higher SNR with the sacrifice of measuring speed. In summary, the newly developed system showed great potential in promoting detection sensitivity as well as measuring speed. This will make substantial progress in dynamically tracking the blood concentration distribution in many clinical areas, such as small animal disease modeling, human brain activity research and thick tissues (for example, breast) diagnosis.


**Abstract:** **BACKGROUND:** Studies suggest that the observation of others' actions leads to enhanced motor skill learning. **OBJECTIVE:** We examined whether others' or self-action observation is effective for standing balance learning. In addition, we examined cortical activation during action observation using functional near-infrared spectroscopy. **METHODS:** Thirty-nine healthy young subjects were assigned randomly to the Control, Other-Observation (O-O), and Self-Observation (S-O) groups. The subjects learned to stand on a tilting platform while maintaining a horizontal position. The Control group alternated each trial with a rest period. The O-O and S-O groups were provided with information related to their performance during the rest period: the O-O group observed another person, while the S-O group observed their previous performance. Cortical activation was assessed by changes of hemoglobin oxygenation (oxyHb). **RESULTS:** A 2-way analysis of variance with repeated measures on balance performance revealed a significant difference in post-training (p < 0.05) and retention (p < 0.01) only in the S-O group. And an increase of oxyHb levels at post-training in the S-O group was observed in the supplementary motor area. **CONCLUSION:** Self-action observation improved standing balance and brain activity during training and at 24 h after training.

102. Visani et al. (2014). **Hemodynamic and EEG Time-Courses During Unilateral Hand Movement in Patients with Cortical Myoclonus. An EEG-fMRI and EEG-TD-fNIRS Study**

**Abstract:** Multimodal human brain mapping has been proposed as an integrated approach capable of improving the recognition of the cortical correlates of specific neurological functions. We used simultaneous EEG-fMRI (functional magnetic resonance imaging) and EEG-TD-fNIRS (time domain functional near-infrared spectroscopy) recordings to compare different hemodynamic methods with changes in EEG in ten patients with progressive myoclonic epilepsy and 12 healthy controls. We evaluated O2Hb, HHb and Blood oxygen level-dependent (BOLD) changes and event-related desynchronization/synchronization (ERD/ERS) in the α and β bands of all of the subjects while they performed a simple motor task. The general linear model was used to obtain comparable fMRI and TD-fNIRS activation maps. We also analyzed cortical thickness in order to evaluate any structural changes. In the patients, the TD-NIRS and fMRI data significantly correlated and showed a significant lessening of the increase in O2Hb and the decrease in BOLD. The post-movement β rebound was
minimal or absent in patients. Cortical thickness was moderately reduced in the motor area of the patients and correlated with the reduction in the hemodynamic signals. The fMRI and TD-NIRS results were consistent, significantly correlated and showed smaller hemodynamic changes in the patients. This finding may be partially attributable to mild cortical thickening. However, cortical hyperexcitability, which is known to generate myoclonic jerks and probably accounts for the lack of EEG β-ERS, did not reflect any increased energy requirement. We hypothesize that this is due to a loss of inhibitory neuronal components that typically fire at high frequencies.

103. Ogoh et al. (2014). **The effect of changes in cerebral blood flow on cognitive function during exercise**

**Abstract:** No studies have identified the direct effect of changes in cerebral blood flow (CBF) on cognitive function at rest and during exercise. In this study, we manipulated CBF using hypercapnic gas to examine whether an increase in CBF improves cognitive function during prolonged exercise. The speed and the accuracy of cognitive function were assessed using the Stroop color-word test. After the Stroop test at rest, the subjects began exercising on a cycling ergometer in which the workload was increased by 0.5 kilopond every minute until a target heart rate of 140 beats/min was achieved. Then, the subjects continued to cycle at a constant rate for 50 min. At four time points during the exercise (0, 10, 20, 50 min), the subjects performed a Stroop test with and without hypercapnic respiratory gas (2.0% CO2), with a random order of the exposures in the two tests. Despite a decrease in the mean blood flow velocity in the middle cerebral artery (MCA Vmean), the reaction time for the Stroop test gradually decreased during the prolonged exercise without any loss of performance accuracy. In addition, the hypercapnia-induced increase in MCA Vmean produced neither changes in the reaction time nor error in the Stroop test during exercise. These findings suggest that the changes in CBF are unlikely to affect cognitive function during prolonged exercise. Thus, we conclude that improved cognitive function may be due to cerebral neural activation associated with exercise rather than global cerebral circulatory condition.

104. Igarashi et al. (2014). **Effects of olfactory stimulation with rose and orange oil on prefrontal cortex activity**

**Abstract:** Objectives: People have been aware of essential oils, which are derived from plants, for a long time. Recently, we have become interested in physiological and subjective effects of daily exposure to essential oils. The primary aim of the present study was to clarify effects of olfactory stimulation with rose or orange oil on prefrontal cortex activity; subjective evaluations of relaxation were also determined.

Setting and interventions: Subjects were exposed for 90 s to air impregnated with either rose or orange essential oil. As a control, subjects wore the same device but inhaled only unimpregnated air. The three stimuli were randomly presented to each subject.

Main outcome measures: Physiological effects were determined by near-infrared time-resolved spectroscopy and a modified semantic differential approach was used to determine subjective evaluations.

Results: The study participants were 20 female university students (mean age 22.5 ± 1.6 years). Olfactory stimulation by rose or orange oil induced: (1) a significant decrease in oxyhemoglobin concentration in the right prefrontal cortex and (2) an increase in “comfortable,” “relaxed,” and “natural” feelings.

Conclusion: These findings indicate that olfactory stimulation by rose or orange oil induces physiological and psychological relaxation.
105. Sperlich et al. (2014). **Repeated apnea-induced contraction of the spleen in cyclists does not enhance performance in a subsequent time-trial**

**Abstract:** Purpose: Splenic contraction induced by repeated apneas has been shown to increase oxygen availability. Our aim was to determine whether repeated maximal voluntary apnea enhances the performance of cyclists in a subsequent 4-km time trial.

Methods: Seven male cyclists [age: 27.1 ± 2.1 years; height: 182 ± 8 cm; body mass: 74.8 ± 9.2 kg; peak oxygen uptake: 56.9 ± 6.6 mL min⁻¹ kg⁻¹ (mean ± SD)] performed a 4-km time trial on an ergometer with and without four prior maximal bouts of apnea interspersed with 2 min of recovery.

Results: The average power output during the time trial was similar with (293 ± 48 W) and without (305 ± 42 W) prior apnea (P = 0.11, d = 0.27). The spleen was reduced in size after the fourth bout of apnea (−12.4 ± 9.0 %), as well as one (−36.6 ± 10.3 %) and 10 min (−19.5 ± 17.9 %) after the time trial, while with normal breathing the spleen was smaller one (−35.0 ± 11.3 %) and 10 min (−23.4 ± 19.7 %) after the time trial. Heart rate; oxygen uptake and carbon dioxide production; tissue oxygen saturation; and the lactate concentration, pH, oxygen saturation, level of hemoglobin and hematocrit of the blood were similar under both conditions.

Conclusions: Our present findings reveal that four apneas by cyclists prior to a 4-km time trial led to splenic contraction, but no change in mean power output, the level of hemoglobin, hematocrit, oxygen saturation of the m. vastus lateralis or oxygen uptake.

106. Hori et al. (2014). **Arterial pressure above the upper cerebral autoregulation limit during cardiopulmonary bypass is associated with postoperative delirium**

**Abstract:** Background: Mean arterial pressure (MAP) below the lower limit of cerebral autoregulation during cardiopulmonary bypass (CPB) is associated with complications after cardiac surgery. However, simply raising empiric MAP targets during CPB might result in MAP above the upper limit of autoregulation (ULA), causing cerebral hyperperfusion in some patients and predisposing them to cerebral dysfunction after surgery. We hypothesized that MAP above an ULA during CPB is associated with postoperative delirium.

Methods: Autoregulation during CPB was monitored continuously in 491 patients with cerebral oximetry index (COx) in this prospective observational study. COx represents Pearson's correlation coefficient between low-frequency changes in regional cerebral oxygen saturation (measured with near-infrared spectroscopy) and MAP. Delirium was defined throughout the postoperative hospitalization based on clinical detection with prospectively defined methods.

Results: Delirium was observed in 45 (9.2%) patients. Mechanical ventilation for >48 h [odds ratio (OR), 3.94; 95% confidence interval (CI), 1.72–9.03], preoperative antidepressant use (OR, 3.0; 95% CI, 1.29–6.96), prior stroke (OR, 2.79; 95% CI, 1.12–6.96), congestive heart failure (OR, 2.68; 95% CI, 1.28–5.62), the product of the magnitude and duration of MAP above an ULA (mm Hg h; OR, 1.09; 95% CI, 1.03–1.15), and age (per year of age; OR, 1.01; 95% CI, 1.01–1.07) were independently associated with postoperative delirium.

Conclusions: Excursions of MAP above the upper limit of cerebral autoregulation during CPB are associated with risk for delirium. Optimizing MAP during CPB to remain within the cerebral autoregulation range might reduce risk of delirium.

107. Reinhard et al. (2014). **Spatial mapping of dynamic cerebral autoregulation by multichannel near-infrared spectroscopy in high-grade carotid artery disease**

**Abstract:** The exact spatial distribution of impaired cerebral autoregulation in carotid artery disease is unknown. In this pilot study, we present a new approach of multichannel near-infrared spectroscopy (mcNIRS) for noninvasive spatial mapping of dynamic autoregulation in carotid artery disease. In 15 patients with unilateral severe carotid artery stenosis or occlusion, cortical hemodynamics in the bilateral frontal cortex were assessed from changes in oxyhemoglobin concentration using 52-channel NIRS (spatial resolution ~2 cm). Dynamic autoregulation was graded by the phase shift between respiratory-induced 0.1 Hz oscillations of blood
pressure and oxyhemoglobin. Ten of 15 patients showed regular phase values in the expected (patho) physiological range. Five patients had clearly outlying irregular phase values mostly due to artifacts. In patients with a regular phase pattern, a significant side-to-side difference of dynamic autoregulation was observed for the cortical border zone area between the middle and anterior cerebral artery (p<0.05). In conclusion, dynamic cerebral autoregulation can be spatially assessed from slow hemodynamic oscillations with mcNIRS. In high-grade carotid artery disease, cortical dynamic autoregulation is affected mostly in the vascular border zone. Spatial mapping of dynamic autoregulation may serve as a powerful tool for identifying brain regions at specific risks for hemodynamic infarction.

108. Lugo et al. (2014). Near-infrared spectroscopy of image clarity perception in the human brain

Abstract: The perception of blur in humans is intrinsic to our visual system, and dioptic power can improve clarity in many cases. This was evaluated experimentally to establish the best correction with dioptic power shifts. We used Near Infrared Spectroscopy (NIRS) to measure Oxy-, Deoxy- and Total-hemoglobin concentration changes in the brain while viewing images and reading a Snellen chart. Participants were tested with their usual correction (no diopter power shift (0 D)), with a 0.25 diopter power shift (0.25 D), and with a 0.5 diopter power shift (0.5 D). The concept of Approximate Entropy (AE) was applied to quantify the regularity of these hemoglobin time series of finite length. AE computations are based on the likelihood that similar templates in a time series remain similar on the next incremental comparison, so that time series with large AE have high irregular fluctuation. We found that the dioptic power shift eliciting the highest AE indicates the clearest visual condition for subjects. This technique may impact the current way in which ophthalmic lenses are prescribed.

109. Bixler et al. (2014). Assessment of tissue heating under tunable near-infrared radiation

Abstract: The time-temperature effects of laser radiation exposure are investigated as a function of wavelength. Here, we report the thermal response of bulk tissue as a function of wavelength from 700 to 1064 nm. Additionally, Monte Carlo simulations were used to verify the thermal response measured and predict damage thresholds based on the response.

110. Steinberg et al. (2014). Robust estimation of cerebral hemodynamics in neonates using multilayered diffusion model for normal and oblique incidences

Abstract: The diffusion approximation is useful for many optical diagnostics modalities, such as near-infrared spectroscopy. However, the simple normal incidence, semi-infinite layer model may prove lacking in estimation of deep-tissue optical properties such as required for monitoring cerebral hemodynamics, especially in neonates. To answer this need, we present an analytical multilayered, oblique incidence diffusion model. Initially, the model equations are derived in vector-matrix form to facilitate fast and simple computation. Then, the spatiotemporal reflectance predicted by the model for a complex neonate head is compared with time-resolved Monte Carlo (TRMC) simulations under a wide range of physiologically feasible parameters. The high accuracy of the multilayer model is demonstrated in that the deviation from TRMC simulations is only a few percent even under the toughest conditions. We then turn to solve the inverse problem and estimate the oxygen saturation of deep brain tissues based on the temporal and spatial behaviors of the reflectance. Results indicate that temporal features of the reflectance are more sensitive to deep-layer optical parameters. The accuracy of estimation is shown to be more accurate and robust than the commonly used single-layer diffusion model. Finally, the limitations of such approaches are discussed thoroughly.
111. Azimipour et al. (2014). Extraction of optical properties and prediction of light distribution in rat brain tissue

Abstract: Predicting the distribution of light inside any turbid media, such as biological tissue, requires detailed information about the optical properties of the medium, including the absorption and scattering coefficients and the anisotropy factor. Particularly, in biophotonic applications where photons directly interact with the tissue, this information translates to system design optimization, precision in light delivery, and minimization of unintended consequences, such as phototoxicity or photobleaching. In recent years, optogenetics has opened up a new area in deep brain stimulation with light and the method is widely adapted by researchers for the study of the brain circuitries and the dynamics of neurological disorders. A key factor for a successful optogenetic stimulation is delivering an adequate amount of light to the targeted brain objects. The adequate amount of light needed to stimulate each brain object is identified by the tissue optical properties as well as the type of opsin expressed in the tissue, wavelength of the light, and the physical dimensions of the targeted area. Therefore, to implement a precise light delivery system for optogenetics, detailed information about the optical properties of the brain tissue and a mathematical model that incorporates all determining factors is needed to find a good estimation of light distribution in the brain. In general, three measurements are required to obtain the optical properties of any tissue, namely diffuse transmitted light, diffuse reflected light, and transmitted ballistic beam. In this report, these parameters were measured in vitro using intact rat brain slices of 500 μm thickness via a two-integrating spheres optical setup. Then, an inverse adding doubling method was used to extract the optical properties of the tissue from the collected data. These experiments were repeated to cover the whole brain tissue with high spatial resolution for the three different cuts (transverse, sagittal, and coronal) and three different wavelengths (405, 532, and 635 nm) in the visible range of the spectrum. A three-dimensional atlas of the rat brain optical properties was constructed based on the experimental measurements. This database was linked to a Monte Carlo toolbox to simulate light distribution in the tissue for different light source configurations.

112. Calabro et al. (2014). Influence of the phase function in generalized diffuse reflectance models: review of current formalisms and novel observations

Abstract: Diffuse reflectance spectroscopy, which has been demonstrated as a noninvasive diagnostic technique, relies on quantitative models for extracting optical property values from turbid media, such as biological tissues. We review and compare reflectance models that have been published, and we test similar models over a much wider range of measurement parameters than previously published, with specific focus on the effects of the scattering phase function and the source-detector distance. It has previously been shown that the dependence of a forward reflectance model on the scattering phase function can be described more accurately using a variable, γ, which is a more predictive variable for reflectance than the traditional anisotropy factor, g. We show that variations in the reflectance model due to the phase function are strongly dependent on the source-detector separation, and we identify a dimensionless scattering distance at which reflectance is insensitive to the phase function. Further, we evaluate how variations in the phase function and source-detector separation affect the accuracy of inverse property extraction. By simultaneously fitting two or more reflectance spectra, measured at different source-detector separations, we also demonstrate that an estimate of γ can be extracted, in addition to the reduced scattering and absorption coefficients.

113. Simon et al. (2014). Time-resolved measurements of the optical properties of fibrous media using the anisotropic diffusion equation

Abstract: Transmittance and reflectance from spruce wood and bovine ligamentum nuchae as two different fibrous media are examined by time-of-flight spectroscopy for varying source detector separations and several orientations of the fibers in the sample. The anisotropic diffusion theory is used to obtain the absorption coefficient and the diffusion coefficients parallel and perpendicular to the fibers. The results are compared to those obtained with the isotropic diffusion theory. It is shown that for increasing source detector separations, the
retrieved optical properties change as expected from Monte Carlo simulations performed in a previous study. This confirms that the anisotropic diffusion theory yields useful results for certain experimental conditions.

114. Salo et al. (2014). Multispectral measurement of contrast in tissue-mimicking phantoms in near-infrared spectral range of 650 to 1600 nm

Abstract: In order to identify the optimal imaging conditions for the highest spatial contrast in biological tissue, we explored the properties of a tissue-mimicking phantom as a function of the wavelengths in a broad range of near-infrared spectra (650 to 1600 nm). Our customized multispectral hardware, which featured a scanning transmission microscope and imaging spectrographs equipped with silicon and InGaAs charge-coupled diode array detectors, allowed for direct comparison of the Michelson contrast obtained from a phantom composed of a honeycomb grid, Intralipid, and India ink. The measured contrast depended on the size of the grid, luminance, and the wavelength of measurements. We demonstrated that at low thickness of the phantom, a reasonable contrast of the objects can be achieved at any wavelength between 700 and 1400 nm and between 1500 and 1600 nm. At larger thicknesses, such contrast can be achieved mostly between 1200 and 1350 nm. These results suggest that distinguishing biological features in deep tissue and developing contrast agents for in vivo may benefit from imaging in this spectral range.


Abstract: Performance assessment of instruments devised for clinical applications is of key importance for validation and quality assurance. Two new protocols were developed and applied to facilitate the design and optimization of instruments for time-domain optical brain imaging within the European project nEUROPt. Here, we present the “Basic Instrumental Performance” protocol for direct measurement of relevant characteristics. Two tests are discussed in detail. First, the responsivity of the detection system is a measure of the overall efficiency to detect light emerging from tissue. For the related test, dedicated solid slab phantoms were developed and quantitatively spectrally characterized to provide sources of known radiance with nearly Lambertian angular characteristics. The responsivity of four time-domain optical brain imagers was found to be of the order of 0.1 m2 sr. The relevance of the responsivity measure is demonstrated by simulations of diffuse reflectance as a function of source-detector separation and optical properties. Second, the temporal instrument response function (IRF) is a critically important factor in determining the performance of time-domain systems. Measurements of the IRF for various instruments were combined with simulations to illustrate the impact of the width and shape of the IRF on contrast for a deep absorption change mimicking brain activation.


Abstract: Mapping of human brain function has revolutionized systems neuroscience. However, traditional functional neuroimaging by positron emission tomography or functional magnetic resonance imaging cannot be used when applications require portability, or are contraindicated because of ionizing radiation (positron emission tomography) or implanted metal (functional magnetic resonance imaging). Optical neuroimaging offers a non-invasive alternative that is radiation free and compatible with implanted metal and electronic devices (for example, pacemakers). However, optical imaging technology has heretofore lacked the combination of spatial resolution and wide field of view sufficient to map distributed brain functions. Here, we present a high-density diffuse optical tomography imaging array that can map higher-order, distributed brain function. The system was tested by imaging four hierarchical language tasks and multiple resting-state networks including the dorsal attention and default mode networks. Finally, we imaged brain function in patients with Parkinson’s disease and implanted deep brain stimulators that preclude functional magnetic resonance imaging.
117. Hou et al. (2014). Research on Diffuse Optical Tomography System in Frequency Domain

Abstract: In the past decades, the requirements of non-invasive, non-radiation in medical imaging diagnosis and treatment is much higher. Diffusion optical tomography (DOT) technology increases more widespread concern. In this paper, a system designed in the frequency domain for diffuse optical tomography (DOT) imaging is described. The experimental platform utilizes 660nm laser modulated to 100MHZ, 16 parallel positions of detection at which a photomultiplier-tube is placed to detect flux of light on the external periphery of the tissue-simulating phantom made by gelatin. The reconstructed image of the absorption and scattering coefficients are obtained by using the Levenberg-Marquardt (L-M) reconstruction algorithm to solve for the optimal fitness between the measurement data and calculated data. This paper puts forward a new method that calculates the flux of area on the external periphery of the model by the forward algorithms to reduce the measurement error, which is caused by the mismatching between the flux of area the photomultiplier detects and the flux of dot the forward algorithms calculate in the traditional method. The experimental result shows that the proposed method can improve the reconstructed image of absorption and scattering coefficients.

Publications from the BORL, Zurich


Abstract: Simultaneous measurement of cortical and peripheral affective processing is relevant in many neuroscientific research fields. The aim was to investigate the influence of different affective task components on the coherence between cortical hemodynamic signals and peripheral autonomic skin potential signals. Seventeen healthy subjects performed four tasks, i.e. a finger-tapping task, a hyperventilation task, a working memory task and a risk-taking task. Cortical hemodynamic responses were measured using functional near-infrared spectroscopy (fNIRS). Peripheral skin conductance responses (SCRs) were assessed using electrodermal activity (EDA). Coherence between the fNIRS and the EDA time series was calculated using the S transform coherence (STC), a method that tests the temporal dynamics between two time series for consistent phase relationships and thus for a functional relationship. The following characteristics of fNIRS-EDA coherence were observed: (1) Simple motor performance was not a contributor to enhanced coherence, as revealed by the finger-tapping task. (2) Changes in respiration rate and/or heart rate acted as relevant contributors to enhanced coherence, as revealed by the hyperventilation task. (3) Working memory performance did not induce changes in coherence, (4) whereas risk-taking behavior was a significant contributor to enhanced coherence. (5) Based on all four tasks, we also observed that coherence may be subject to habituation or sensitization effects over the trial-to-trial course of a task. Increased fNIRS-EDA coherence may be an indicator of a psychophysiological link between the underlying cortical and peripheral affective systems. Our findings are relevant for several neuroscientific research areas seeking to evaluate the interplay between cortical and peripheral affective performance.

119. Demel et al. (2014). Effect of different assumptions for brain water content on absolute measures of cerebral oxygenation determined by frequency-domain near-infrared spectroscopy in preterm infants: an observational study

Abstract: Background: Brain-water content (BWC) decreases with maturation of the brain and potentially affects parameters of cerebral oxygenation determined by near-infrared spectroscopy (NIRS). Most commercially available devices do not take these maturational changes into account. The aim of this study was to determine the effect of different assumptions for BWC on parameters of cerebral oxygenation in preterm infants. Methods: Concentrations of oxy-, deoxy- and total hemoglobin and regional cerebral oxygen saturation (reStO2) were calculated based on absolute coefficients of absorption and scattering determined by multi-distance
Frequency-Domain-NIRS assuming BWCs of 75-95%, which may be encountered in newborn infants depending on gestational and postnatal age. Results: This range of BWC gave rise to a linear modification of the assessed NIRS parameters with a maximum change of 10%. This may result in an absolute overestimation of rStO2 by (median (range)) 4 (1–8)%, if the calculation is based on the lowest BWC (75%) in an extremely preterm infant with an anticipated BWC of 95%. Conclusion: Clinicians wishing to rely on parameters of cerebral oxygenation determined by NIRS should consider that maturational changes in BWC not taken into account by most devices may result in a deviation of cerebral oxygenation readings by up to 8% from the correct value.

120. Krehel et al. (2014). Development of a luminous textile for reflective pulse oximetry measurements

Abstract: In this paper, a textile-based sensing principle for long term photoplethysmography (PPG) monitoring is presented. Optical fibers were embroidered into textiles such that out-coupling and in-coupling of light was possible. The “light-in-light-out” properties of the textile enabled the spectroscopic characterization of human tissue. For the optimization of the textile sensor, three different carrier fabrics and different fiber modifications were compared. The sample with best light coupling efficiency was successfully used to measure heart rate and SpO2 values of a subject. The latter was determined by using a modified Beer-Lambert law and measuring the light attenuation at two different wavelengths (632 nm and 894 nm). Moreover, the system was adapted to work in reflection mode which makes the sensor more versatile. The measurements were additionally compared with commercially available system and showed good correlation.

121. Ulrich et al. (2014). Cerebral Oxygenation in Patients With OSA: Effects of Hypoxia at Altitude and Impact of Acetazolamide

Abstract: BACKGROUND: Sleep-disordered breathing may impair cerebral oxygenation in patients with OSA syndrome, in particular during altitude travel. We studied cerebral tissue oxygenation (CTO) at low and moderate altitude in patients with OSA and evaluated whether acetazolamide improved CTO.

METHODS: Eighteen patients with OSA living at < 600 m discontinued CPAP therapy during studies in Zurich (490 m) and during two sojourns of 3 days in the Swiss Alps (2 days at 1,860 m and 1 day at 2,590 m) separated by a 2-week washout period at < 600 m. Patients received acetazolamide (2 × 250 mg/d) or placebo at altitude in a randomized, double-blind, crossover design. Nocturnal polysomnography, including CTO monitoring by near-infrared spectroscopy (NIRS), was performed.

RESULTS: At 490 m, medians of CTO, peripheral oxygen saturation as measured by pulse oximetry (SpO2), and apnea/hypopnea index were 65%, 93%, and 57.3/h, respectively. At 2,590 m, on placebo, the corresponding values were 59%, 86%, and 86.4/h, respectively (P < .05, all corresponding comparisons). Acetazolamide increased CTO and SpO2 at 2,590 m by mean values of 2% (95% CI, 0%-4%) and 2% (95% CI, 1%-3%), respectively, and reduced the apnea/hypopnea index by 23.4/h (95% CI, 14.0-32.8/h) (P < .05, all changes). Cerebral total hemoglobin concentration, a NIRS-derived surrogate reflecting regional cerebral blood volume, increased by a similar degree in response to apneas at 490 m and 2,590 m and during acetazolamide and placebo treatment.

CONCLUSIONS: In patients with OSA staying at altitude, nocturnal cerebral and arterial oxygenation were reduced in association with exacerbated sleep apnea. Acetazolamide partially improved CTO, SpO2, and sleep apnea without impairing the cerebral blood flow response to apneas.