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

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Number of papers included: **83**

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

1. Weenink et al. (2014). **Detection of cerebral arterial gas embolism using regional cerebral oxygen saturation, quantitative electroencephalography, and brain oxygen tension in the swine**

Abstract: Background: Cerebral air emboli occur as a complication of invasive medical procedures. The sensitivity of cerebral monitoring methods for the detection of air emboli is not known. This study investigates the utility of electroencephalography and non-invasively measured cerebral oxygen saturation in the detection of intracerebrovascular air. New method: In 12 pigs oxygen saturation was continuously measured using transcranial near-infrared spectroscopy and oxygen tension was continuously measured using intraparenchymal probes. Additionally, quantitative electroencephalography and microdialysis were performed. Doses of 0.2, 0.4, 0.8, and 1.6 ml of air were injected into the cerebral arterial vasculature through a catheter. Results: Oxygen saturation and electroencephalography both reacted almost instantaneously on the air emboli, but were less sensitive than the intraparenchymal oxygen tension. There was reasonable correlation (ρ ranging from 0.417 to 0.898) between oxygen saturation, oxygen tension, electroencephalography and microdialysis values. Comparison with existing methods: Our study is the first to demonstrate the effects of cerebral air emboli using multimodal monitoring, specifically on oxygen saturation as measured using near-infrared spectroscopy. Conclusions: Our results show that non-invasively measured oxygen saturation and quantitative electroencephalography can detect the local effects of air emboli on cerebral oxygenation, but with reduced sensitivity as compared to intraparenchymal oxygen tension. Prospective human studies using multimodal monitoring incorporating electroencephalography and oxygen saturation should be performed.

2. Belohlavek et al. (2014). **Feasibility of cerebral blood flow and oxygenation monitoring by continuous transcranial Doppler combined with cerebral oximetry in a patient with refractory cardiac arrest treated by extracorporeal life support**

Abstract: The adequacy of cerebral blood flow and the level of regional oxygen saturation during CPR and early post-resuscitation phases assuring favorable neurological outcome are not known. We demonstrate the feasibility of cerebral blood flow and oxygenation monitoring by a continuous transcranial Doppler combined with cerebral oximetry in a patient with refractory cardiac arrest treated by extracorporeal life support.

3. Miura et al. (2014). **Near-infrared spectroscopy and plasma homovanillic acid levels in bipolar disorder: a case report**

Abstract: Misdiagnosis of bipolar disorder is a serious, but not unusual problem for patients. Nevertheless, there are few biomarkers for distinguishing unipolar and bipolar disorder. Near-infrared spectroscopy (NIRS) is a noninvasive and useful method for the measurement of hemoglobin concentration changes in the cortical surface area, which enables the assessment of brain function. We measured NIRS and plasma monoamine metabolite levels in a patient with bipolar disorder. A 22-year-old man was admitted due to major depression. At admission, NIRS findings showed oxygenated hemoglobin reincrease in the posttask period, which is characteristic of schizophrenia. After treatment with paroxetine, he became manic with psychotic symptoms. His

plasma level of homovanillic acid just before the manic switch was ten times higher than that just after paroxetine initiation. Treatment with lithium and antipsychotics was successful, and plasma homovanillic acid decreased after treatment. In this case, the NIRS findings may predict a possible risk of a manic switch, which is likely induced by paroxetine. NIRS may be able to help distinguish unipolar and bipolar disorder in clinical settings.

4. Osaka et al. (2014). **Neural Synchronization During Cooperated Humming: A Hyperscanning Study Using fNIRS**

Abstract: We examined the neural difference between cooperated face-to-face humming by simultaneously measuring two brains using a hyperscanning approach. Results showed a significant increase in the neural synchronization between two brains in the right inferior frontal cortex during a non-face-to-face humming. Thus we found the inferior frontal cortex of the right brain plays a critical role in vocal humming.

5. Manfredini et al. (2014). **Acute oxygenation changes on ischemic foot of a novel intermittent pneumatic compression device and of an existing sequential device in severe peripheral arterial disease**

Abstract: Background: Intermittent pneumatic compression (IPC) improves haemodynamics in peripheral arterial disease (PAD), but its effects on foot perfusion were scarcely studied. In severe PAD patients we measured the foot oxygenation changes evoked by a novel intermittent IPC device (GP), haemodynamics and compliance to the treatment. Reference values were obtained by a sequential foot-calf device (SFC). Methods: Twenty ischemic limbs (Ankle-Brachial Index = 0.5 ± 0.2) of 12 PAD patients (7 male, age: 74.5 ± 10.8 y) with an interval of 48 ± 2 hours received a 35 minute treatment in supine position with two IPC devices: i) a Gradient Pump (GP), which slowly inflates a single thigh special sleeve and ii) an SFC (ArtAssist®, ACI Medical, San Marcos, CA, USA), which rapidly inflates two foot-calf sleeves. Main outcome measure: changes of oxygenated haemoglobin at foot (HbO2foot) by continuous near-infrared spectroscopy recording and quantified as area-under-curve (AUC) for periods of 5 minutes. Other measures: haemodynamics by echo-colour Doppler (time average velocity (TAV) and blood flow (BF) in the popliteal artery and in the femoral vein), patient compliance by a properly developed form. Results: All patients completed the treatment with GP, 9 with SFC. HbO2foot during the working phase, considered as average value of the 5 minutes periods, increased with GP (AUC 458 ± 600 to 1216 ± 280) and decreased with SFC (AUC 231 ± 946 to −1088 ± 346), significantly for most periods ($P < 0.05$). The GP treatment was associated to significant haemodynamic changes from baseline to end of the treatment (TAV = 10.2 ± 3.3 to 13.5 ± 5.5 cm/sec, $P = 0.004$; BF = 452.0 ± 187.2 to 607.9 ± 237.8 ml/sec, $P = 0.0001$), not observed with SFC (TAV = 11.2 ± 3.4 to 11.8 ± 4.3 cm/sec; BF = 513.8 ± 203.7 to 505.9 ± 166.5 ml/min, P = n.s.). GP obtained a higher score of patient compliance ($P < 0.0001$). Conclusions: A novel IPC thigh device, unlike a traditional SFC device, increased foot oxygenation in severe PAD, together with favourable haemodynamic response and high compliance to the treatment under the present experimental conditions.

6. Rhondali et al. (2014). **Impact of sevoflurane anesthesia on brain oxygenation in children younger than 2 years**

Abstract: Objective/Aim: To assess the impact of sevoflurane and anesthesia-induced hypotension on brain oxygenation in children younger than 2 years. Background: Inhalational induction with sevoflurane is the most commonly used technique in young children. However, the effect of sevoflurane on cerebral perfusion has been only studied in adults and children older than 1 year. The purpose of this study was to assess the impact of sevoflurane anesthesia on brain oxygenation in neonates and infants, using near-infrared spectroscopy. Methods: Children younger than 2 years, ASA I or II, scheduled for abdominal or orthopedic surgery were included. Induction of anesthesia was started by sevoflurane 6% and maintained with an expired fraction of

sevoflurane 3%. Mechanical ventilation was adjusted to maintain an endtidal CO2 around 39 mmHg. Brain oxygenation was assessed measuring regional cerebral saturation of oxygen (rSO2c), measured by NIRS while awake and 15 min after induction, under anesthesia. Mean arterial pressure (MAP) variation was recorded. Results: Hundred and ninety-five children were included. Anesthesia induced a significant decrease in MAP (−27%). rSO2c increased significantly after induction (+18%). Using children age for subgroup analysis, we found that despite MAP reduction, rSO2c increase was significant but smaller in children ≤6 months than in children >6 months (≤6 months: rSO2c = +13%, >6 months: rSO2c = +22%; P < 0.0001). Interindividual comparison showed that, during anesthesia at steady-state with comparable CMRO2, rSO2c values were significantly higher when MAP was above 36 mmHg. And the higher the absolute MAP value during anesthesia was, the higher the rSO2c was. We observed a rSO2c variation ≤0 in 21 patients among the 195 studied, and the majority of these patients were younger than 6 months (n = 19). No increase or decrease of rSO2c during anesthesia despite reduction of CMRO2 can be explained by a reduction of oxygen supply. Using the ROC curves, we determined that the threshold value of MAP under anesthesia, associated with rSO2c variation ≤0%, was 39 mmHg in all the studied population (AUC: 0.90 ± 0.02; P < 0.001). In children younger than 6 months, this value of MAP was 33 mmHg, and 43 mmHg in children older than 6 months. Conclusion: Despite a significant decrease of MAP, 1 MAC of sevoflurane induced a significant increase in regional brain oxygenation. But subgroup analysis showed that MAP decrease had a greater impact on brain oxygenation, in children younger than 6 months. According to our results, MAP value during anesthesia should not go under 33 mmHg in children ≤6 months and 43 mmHg in children >6 months, as further changes in MAP, PaCO2 or hemoglobin during anesthesia may be poorly tolerated by the brain.

7. Zweifel et al. (2014). **Continuous time-domain monitoring of cerebral autoregulation in neurocritical care**

Abstract: Integration of various brain signals can be used to determine cerebral autoregulation in neurocritical care patients to guide clinical management and to predict outcome. In this review, we will discuss current methodology of multimodal brain monitoring focusing on secondary 'reactivity indices' derived from various brain signals which are based on a 'moving correlation coefficient'. This algorithm was developed in order to analyze in a time dependent manner the degree of correlation between two factors within a time series where the number of paired observations is large. Of the various primary neuromonitoring sources which can be used to calculate reactivity indices, we will focus in this review on indices based on transcranial Doppler (TCD), intracranial pressure (ICP), brain tissue oxygenation (PbtO2) and near infrared spectroscopy (NIRS). Furthermore, we will demonstrate how reactivity indices can show transient changes of cerebral autoregulation and can be used to optimize management of arterial blood pressure (ABP) and cerebral perfusion pressure (CPP).

8. Choi et al. (2014). **Intraoperative Renal Regional Oxygen Desaturation Can Be a Predictor for Acute Kidney Injury after Cardiac Surgery**

Abstract: Objective: To evaluate the usefulness of renal regional oxygen saturation (renal rSO2) in predicting the risk of acute kidney injury (AKI) after cardiac surgery. Design: A prospective observational study. Setting: Tertiary care university hospital. Participants: One hundred patients undergoing cardiac surgery. Interventions: Renal rSO2 was monitored continuously by near-infrared spectroscopy (NIRS) throughout the anesthetic period. Measurements and Main Results: Postoperative AKI was defined using the Risk, Injury, Failure, Loss, and End-stage (RIFLE) criteria. Of 95 patients who were included in the final analysis, 34 patients developed AKI after surgery. Recorded renal rSO2 data were used to calculate the total duration of the time when renal rSO2 was below the threshold values of 70%, 65%, 60%, 55%, and 50%. The total periods when the renal rSO2 level was below each of the threshold values were significantly longer in patients with AKI than in those without AKI ($p = 0.001$ or $p<0.001$). Receiver operating characteristic (ROC) curve analysis was used to evaluate the predictive power of renal rSO2 for AKI. The ROC curve analysis showed that renal rSO2 could predict the risk of AKI with statistical significance and that a renal rSO2<55% had the best performance (area under the curve–ROC, 0.777;

95% CI, 0.669-0.885; p<0.001). Multivariate logistic regression analysis revealed that AKI significantly correlated with the duration of renal rSO2<55% (p = 0.002) and logistic EuroSCORE (p = 0.007). Conclusions: Intraoperative renal regional oxygen desaturation can be a good predictor of AKI in adult patients undergoing cardiac surgery.

9. Carbone et al. (2014). **Diffuse reflectance optical topography: location of inclusions in 3*D* and detectability limits**

Abstract: In the present contribution we investigate the images of CW diffusely reflected light for a point-like source, registered by a CCD camera imaging a turbid medium containing an absorbing lesion. We show that detection of μa variations (absorption anomalies) is achieved if images are normalized to background intensity. A theoretical analysis based on the diffusion approximation is presented to investigate the sensitivity and the limitations of our proposal and a novel procedure to find the location of the inclusions in 3D is given and tested. An analysis of the noise and its influence on the detection capabilities of our proposal is provided. Experimental results on phantoms are also given, supporting the proposed approach.

10. Halliday et al. (2014). **Brain imaging of nutrition related cognitive development in rural Gambia: studies from birth to 24 months of age (619.1)**

Abstract: Appropriate nutrition in the first 1000 days of life is essential for optimal brain development and function. Neurobehavioral assessments of cognitive function can only be used to detect effects of nutritional deficiencies once they reach the point of observable behaviour, thus reducing the possibility of targeted early intervention strategies. The aim of this study was to demonstrate the use of optical imaging as an assessment tool for cognitive function in the first two years of life for nutrition based studies in a resource poor setting. Near infrared spectroscopy (NIRS) is an optical imaging technique which measures the haemodynamic response to neuronal activation. A typical system comprises pairs of optical sources and detectors placed over the scalp using a lightweight headband. Each source-detector pair provides a measure of regional changes in haemodynamics from which an image of localised brain function can be reconstructed. NIRS is completely non invasive, systems are portable, easy to setup and run, protocols are tolerant of participant motion, and non experts can easily be trained to perform the studies. We transported an NIRS system to a field station in rural Gambia to study infants from three age groups (4-8 month-olds n = 24; 9-13 month olds n = 26; 18-24 month-olds, n = 20). NIRS was used to measure brain activation to visual and auditory social and non social stimuli. Significant activation was seen during auditory social (e.g., laughter) compared to auditory non social (e.g., toy rattles) conditions - as well as to visual social (human peek-a-boo) compared to visual non social (transport images) - in channels localised over the right posterior temporal hemisphere. These results confirm the viability of optical neuroimaging techniques to assess cognitive function in resource poor settings, and suggest that vocal selectivity can be used to differentiate neurodevelopmental trends in visual and auditory processing during the critical first 1000 days of life.

11. Tam et al. (2014). **Temporal decoupling of oxy- and deoxy-hemoglobin hemodynamic responses detected by functional near-infrared spectroscopy (fNIRS)**

Abstract: This study provides experimental evidence that there is temporal decoupling between the hemodynamic responses of oxy- and deoxy-hemoglobin (Hb) as detected by functional near-infrared spectroscopy (fNIRS). Using 64 spatially distributed optrodes to record motor cortical activities during a free arm movement task (right-left and front-back movements), we detected that the temporal profile of oxy- and deoxy-Hb responses are desynchronized and decoupled (i.e., oxy- and deoxy-Hb levels do not rise and fall at the same time). We correlated four different measures of hemodynamic profiles with the arm movements, namely, oxy- (HbO2) and deoxy-hemoglobin (Hb) and their summation (HbO2 + Hb) and difference (HbO2 - Hb) signals. These measures correspond to the changes in oxygen delivery, oxygen extraction, total blood volume delivered, and total

oxygenation with specific movement directions, respectively. They revealed different components of the hemodynamic response in a localized neuronal population in the motor cortex. The results suggested that, by using these four measures, oxygen delivery and oxygen extraction can be coupled in one movement direction, but decoupled in another movement direction for the same human subject executing the same movement task. Oxygen delivery and oxygen extraction do not always co-vary together temporally. Thus, using a single measure of oxygen delivery or extraction alone may not be sufficient to determine whether the cortical area is activated or deactivated. Rather, a combination of all four measures of hemodynamic signals that represent temporal coupling and decoupling of oxygen delivery and extraction is needed to differentiate the temporal profiles of neural activation and deactivation. It demonstrated that different hemodynamic measures can reveal temporally decoupled activation/deactivation patterns differentially during the right-left and front-back motor task. Therefore, relying on a single measure of deoxy-Hb may be insufficient to characterize the neural responses without the oxy-Hb measure. Orthogonal arm movement (right-left vs. front-back) directions can be differentiated based on the differential temporally coupled and decoupled hemodynamics.

12. Jelzow et al. (2014). **Separation of superficial and cerebral hemodynamics using a single distance time-domain NIRS measurement**

Abstract: In functional near-infrared spectroscopy (fNIRS) superficial hemodynamics can mask optical signals related to brain activity. We present a method to separate superficial and cerebral absorption changes based on the analysis of changes in moments of time-of-flight distributions and a two-layered model. The related sensitivity factors were calculated from individual optical properties. The method was validated on a two-layer liquid phantom. Absorption changes in the lower layer were retrieved with an accuracy better than 20%. The method was successfully applied to in vivo data and compared to the reconstruction of homogeneous absorption changes.

13. Caicedo et al. (2014). **Differences in the cerebral hemodynamics regulation mechanisms of premature infants with intra-ventricular hemorrhage assessed by means of phase rectified signal averaging**

Abstract: Cerebral hemodynamics regulation consists of several mechanisms that try to keep brain homeostasis. In premature infants, due to the immaturity of their cerebral vascular bed, these mechanisms might be impaired exposing their brain to damage. The status of the cerebral regulation mechanism is classically assessed by measuring the coupling between some systemic variables, such as Mean arterial blood pressure (MABP) and concentration of blood gases, with surrogate measurements for cerebral blood flow, such as brain tissue oxygenation (rScO2) measured by means of Near-infrared Spectroscopy. We hypothesized that the coupled dynamics between systemic variables and rScO2 is different in premature infants that suffered from brain damage than in those with a favorable clinical outcome. Therefore, we explore the use of phase rectified signal averaging (PRSA) and bi-variate PRSA (BPRSA) in order to identify these differences. We found that the coupled dynamics between changes in MABP and cerebral oxygenation was different in premature infants that suffered III-IV grade intra-ventricular haemorrhage (IVH), when compared to control subjects.

14. Saikia et al. (2014). **High-Speed GPU-Based Fully Three-Dimensional Diffuse Optical Tomographic System**

Abstract: We have developed a graphics processor unit (GPU-) based high-speed fully 3D system for diffuse optical tomography (DOT). The reduction in execution time of 3D DOT algorithm, a severely ill-posed problem, is made possible through the use of (1) an algorithmic improvement that uses Broyden approach for updating the Jacobian matrix and thereby updating the parameter matrix and (2) the multinode multithreaded GPU and CUDA (Compute Unified Device Architecture) software architecture. Two different GPU implementations of DOT programs are developed in this study: (1) conventional C language program augmented by GPU CUDA and

CULA routines (C GPU), (2) MATLAB program supported by MATLAB parallel computing toolkit for GPU (MATLAB GPU). The computation time of the algorithm on host CPU and the GPU system is presented for C and Matlab implementations. The forward computation uses finite element method (FEM) and the problem domain is discretized into 14610, 30823, and 66514 tetrahedral elements. The reconstruction time, so achieved for one iteration of the DOT reconstruction for 14610 elements, is 0.52 seconds for a C based GPU program for 2-plane measurements. The corresponding MATLAB based GPU program took 0.86 seconds. The maximum number of reconstructed frames so achieved is 2 frames per second.

15. Tabby et al. (2014). **Non Invasive Blood Flow Monitoring with Functional Near Infrared Spectroscopy Correlation with Pain Self-Assessment in Subjects Receiving Infusions for Chronic Migrain (P1.264)**

Abstract: Objective: To determine if fNIRS can demonstrate changes in frontal cortical blood flow during pharmacological infusions for migraineBackgroundAcute migraine pain might result in part from the increase in cerebral blood flow to meningeal arteries. The most commonly used infusions to treat migraine at our institution include Magnesium, valproic acid, and dihydroergotamine and lacosamide. To date no study has been made to investigate the link between changes in blood flow in response to infusions for migraine versus changes in pain experienced.Design/methodsFunctional near-infrared spectroscopy system (fNIRS) is a relatively inexpensive, rapid, non-invasive and safe technique to monitor frontal cerebrovascular dynamics. We studied 36 consecutive patients who were given 4 of the most commonly used infusions as listed above. Patients were being treated for chronic migraine. We used a multisource detector fNIR device, measuring each patient's cerebral blood flow for a period of 10 minutes at the start of their infusion. The device contained 2 probes, each with 1 source and 3 detectors. It had one near channel to measure superficial blood flow and two far channels to measure frontal cortical blood flow. This multi-distance approach provided separate measurements of the autonomic response and cortical blood flow. Patients scored their pain on a 1-10 scale, before and after the infusion.Results Medications that caused the largest change in blood flow also improved the pain the most significantly. Conclusion fNIR can be a cost-effective and reliable tool to document changes in blood flow in response to intravenous medication. Cerebral blood flow increases correlated with pain improvement.

16. Sannagowdara et al. (2014). **Hemodynamic Changes Associated with Interictal Epileptiform Activities Using Simultaneous Video Electro-encephalography (EEG)/Near Infrared Spectroscopy (NIRS) in Patient Self Control Study (P4.330)**

Abstract: To correlate focal epileptiform activities with regional cerebral oxygen saturation.BACKGROUND: NIRS is a non-invasive method for continuous measuring of cerebral oxygenation (SaO2), which has been used to monitor cerebral oxygenation and blood flow in various conditions. Different types of hemodynamic changes during seizures have been described: cerebral blood flow and volume may increase or decrease in relation to hyper or hypometabolism. Cerebral Somanetic Oximeter monitor is a FDA approved device, evaluates changes in regional hemoglobin oxygen saturation using single-use, dual-detector sensors that measure photon return from 2 depths of penetration (730nm and 810nm). DESIGN/METHODS: This study included 4 patients age from 5 to 17 years with medically refractory epilepsy - partial complex seizures, undergoing pre-surgical evaluation. Informed consent was obtained from the parents of all subjects. This study was approved by the Medical College of Wisconsin Institutional Review Board. RESULTS: Two patients had hypometabolic area, which confirmed by PET scan, showed clear low hemodynamic changes (20% decreases) in NIRS compared to the contra lateral hemisphere. Two patients had baseline hemispheric hyper-perfusion on NIRS, which were correlated with baseline more epileptiform activity compared to contralateral hemisphere. CONCLUSIONS: This study showed a clear hemodynamic response associated with interictal epileptiform discharges and during ictal events. The hemodynamic changes observed in NIRS study could potentially provide further insight into the pathophysiology of the evolution of seizures. NIRS could become useful adjunct to EEG. It's inexpensive, portable, and has high

temporal resolution.Study Supported by:This study was supported by the Bleser Endowed Chair in Neurology (Dr. Whelan), the Baumann Research Endowment (Dr. Whelan), and a Covidien NIRS Grant (Dr. Whelan).

17. Fayyaz et al. (2014). **Cortical Hemodynamics Assessment in ALS During Cognitive Testing Using Functional Near Infrared Spectroscopy (fNIR) (P4.100)**

Abstract: To examine frontal cortex oxygen utilization during cognitive tasks in amyotrophic lateral sclerosis (ALS) patients using functional near infrared spectroscopy (fNIR).BACKGROUND: Many ALS patients have cognitive deficits likely related to pathology within the frontal lobes. fNIR is a non-invasive technology that allows for evaluation of oxygen utilization by the prefrontal cortex (PFC). DESIGN/METHODS: fNIR was performed on 17 ALS subjects and 17 healthy controls (HC) comparing oxygen utilization and testing accuracy during three different cognitive tasks (Psychomotor Vigilance Test(PVT), a sustained-attention, visual-response task, the Number Interference Test(NIT) a three-part computerized adapation of the Stroop Test and the King-Devick Test(KDT), a three-part rapid number naming task. Relationships between task performance and brain oxygenation were examined. RESULTS: Significant relationships between oxygenation and task performance were identified in several areas. While the left PFC in controls demonstrated a positive correlation to response time on the PVT (R>0.527, p<0.036), negative correlations to number of errors in task 1 (R=-0.523, p=0.038) and task 3 (R=-0.558, p=0.025) of the NIT and the response time in task 2 (R=-0.505, p=0.046, none of these correlations were mirrored in the ALS group. During the KDT, oxygenation demonstrated a positive relationship to completion time in the ALS group during tasks 1 (R=0.673, p=0.006) and 2 (PFC, R>0.515, p<0.050), which was not seen in HC. CONCLUSIONS: Differences in oxygen utilization compared to HC were seen in several areas. In ALS, the lack of correlations during NIT and PVT testing may indicate that early in disease CNS perfusion is not sensitive to workload. There was increased oxygen consumption on KDT Testing suggesting that for ALS subjects this task more difficult, requiring greater mental effort. Future studies are needed to determine the correlation of abnormalities in fNIR to cognitive test results to examine whether fNIR will be useful to detect differences in frontal lobe function. Study Supported by: DUCOM Translational Grant and ALS Hope Foundation.

18. Edwards et al. (2014). **Functional Near-Infrared Spectroscopy (fNIR) Based Detection of Increased Prefrontal Cortex Activity in Frontotemporal Dementia (P3.217)**

Abstract: OBJECTIVE: To detect hemodynamic changes using Functional Near-Infrared Spectroscopy (fNIR) in patients with Frontotemporal Dementia (FTD) compared with Amyotrophic Lateral Sclerosis (ALS) and control subjects.BACKGROUND: It is well recognized that both ALS and FTD have frontally mediated cognitive deficits. Furthermore, it is now known that there is genetic overlap in individuals with ALS and FTD (C9ORF72 and TDP-43 binding protein). Given that both have frontal pathology; we compared oxygen metabolism in ALS and FTD subjects using fNIR. fNIR is a non-invasive, safe and portable technology that allows us to determine task related brain activity in the prefrontal cortex (PFC).DESIGN/METHODS: fNIR evaluation was performed on 17 ALS, 9 FTD and 17 healthy controls (HC),comparing oxygen utilization during three different cognitive tests (Psychomotor Vigilance Test (PVT), Number Interference Test (NIT) and the King-Devick Test (KDT)). The PVT is a sustained-attention,visual-response task, and the KDT, a three-part rapid number naming task,and the NIT, a three-part computerized adapation of the Stroop Test, which targets working memory and maintenance of a complex mental set. Between group differences were assessed by Welch ANOVAs (p=0.10) to account for unequal sample sizes and variances.RESULTS: Significant differences in oxygenation were observed during the KDT in both the Right F(2,14.774)=7.581, p=0.005 (ALS=0.121±0.033,FTD=0.352±0.292, HC=0.033±0.065) and Left F(2,14.403)=4.847,p=0.025 (ALS=0.076±0.096, FTD=0.250±0.237, HC=0.022±0.053) PFC. Bonferroni post-hoc analysis revealed significant differences between FTD and HC (p<0.001), as well as FTD and ALS (p<0.009), but not between ALS and HC (p>0.289). No significant differences between groups were observed during the NIT or PVT.CONCLUSIONS: fNIR detected increased oxygen utilization in the PFC of FTD subjects compared to both ALS and control subjects during tests that target working memory. Further investigation of fNIR as a

diagnostic tool and possible biomarker of frontal lobe involvement in dementias should be pursued.Study Supported by:DUCOM Translational Grant and ALS Hope Foundation.

19. Li et al. (2014). **Verification of additional merits of a bimanual-coordinated rehabilitation robot using near-infrared spectroscopic technology**

Abstract: Using our designed robot, previous work has confirmed that bimanual training induced greater oxygenated-hemoglobin concentration than unilateral-limb training. However, the inter-hemispheric asymmetry of oxygenated-hemoglobin concentration was not compared between the bimanual and unilateral-limb patterns. To confirm the merits of our designed robot based on cerebral hemoglobin activation, 18 healthy subjects performed bimanual and unilateral-limb tasks in active-resisted mode and active-assisted mode for the right and left control sides (determines from that which limb provides a larger force). Analyses of variance were performed to compare the laterality index (LI) of two hemispheres between the two control sides, and to compare oxygenated-hemoglobin concentration between the different training patterns. The difference of LI between the two control sides was distinct in unilateral-limb patterns ($p = 0.029$) but not obvious in bimanual patterns. As for the oxygenated-hemoglobin, active-resisted tasks induced a higher concentration than active-assisted tasks in the left control side ($p = 0.048$). Results demonstrated that the proposed bimanual training induced the functional integrity of two hemispheres, and the robot is favorable for improving bimanual movement-coordination function. Additionally, active-resisted tasks had a higher difficulty level than active-assisted task. Therefore, the robot has a potential for delivering strength enhancement training in bimanual patterns.

20. Liao et al. (2014). **Near Infrared Optical Technologies to Illuminate the Status of the Neonatal Brain**

Abstract: The neurodevelopmental outcome of at-risk infants in the neonatal intensive care unit (NICU) is concerning despite steady improvement in the survival rate of these infants. Our current management is often complicated by delayed realization of cerebral deficits due to late manifestation and lack of effective screening tools and neuroimaging/monitoring techniques that are suitable for sick neonates at the bedside. Near infrared specstrocopy (NIRS) is a noninvasive, safe, and portable technique providing a wide range of cerebral hemodynamic contrasts for evaluating the brain. The current state of NIRS technology can be devided into three generations. The first generation represents conventional trend monitoring oximeters that are currently the most widely used in the clinical settings, while the second generation focuses on improving the quantitive accuracy of NIRS measurements by advanced optical techniques. The emergence of diffuse optical imaging (DOI) represents a third generation which opens up more potential clinical applications by providing regional comparisons of brain oximetry and functions either at rest or in response to interventions. Successful integration of NIRS/DOI into the clinical setting requires matching the different capabilities of each instrument to specific clinical goals.

21. Ikeda et al. (2014). **Association of the five-factor personality model with prefrontal activation during frontal lobe task performance using two-channel near-infrared spectroscopy**

Abstract: Aim: The aim of this study was to investigate the biological background of the five-factor model using near-infrared spectroscopy and cognitive tasks. Methods: Twenty right-handed healthy volunteers participated in this study. Their personality traits were assessed using the NEO Five-Factor Inventory, and changes in oxyhemoglobin concentration ([oxy-Hb]) were measured during cognitive tasks using a wireless near-infrared spectroscopy. Results: The average [oxy-Hb] in the right prefrontal area had a significant positive correlation with the agreeableness score during the Stroop test at incongruent stimulus block. For the verbal fluency task, there were no significant correlations of bilateral [oxy-Hb] changes with any items. Conclusion: Higher agreeableness scores may involve less suppression to the default mode network related to resting state brain

function. Keeping selective attention during the Stroop test may require more power of concentration than retrieving words during the verbal fluency task.

22. Shadgan et al. (2014). **Diagnosis of testicular torsion using near infrared spectroscopy: A novel diagnostic approach**

Abstract: We report a case of testicular torsion in a 14-month old boy. Testicular ischemia was suspected based on history and clinical presentations. The patient was referred following 24 hours of left acute scrotum. Erythema, swelling and tenderness associated with nausea and emesis were present, but the patient was not febrile. We used a spatially resolved near-infrared spectroscopy (SR-NIRS) device to study and compare the tissue saturation index (TSI) on both right and left spermatic cords. The TSI was significantly reduced in the left side. Both testicles were surgically explored and the left testis was found non-viable with a 1080-degree intra-vaginal torsion. NIRS monitoring of spermatic cord oxygen saturation appears feasible as a non-invasive bedside optical method to identify testicular torsion.

23. Abramo et al. (2014). **Cerebral oximetry with blood volume index in asystolic pediatric cerebrospinal fluid malfunctioning shunt patients**

Abstract: - no abstract available -

24. Pfeifer et al. (2014). **Real-Time Classification of Actual vs Imagery Finger Tapping Using Functional Near-Infrared Spectroscopy**

Abstract: Using a real-time method and LS-SVM, fNIRS signals from actual and imagery finger tapping experiments are successfully classified. This method can achieve an average accuracy of 76% using a time window of only 0.4seconds.

25. Cano et al. (2014). **Analysis of Brain Networks during Resting State with Near-Infrared Spectroscopy**

Abstract: We investigated the resting-state functional connectivity of near-infrared spectroscopy data of the whole head with complex networks. We show that the graph parameters measured for 11 healthy adults are similar, despite variances in their networks.

26. Selb et al. (2014). **Sensitivity of Continuous-Wave NIRS and Diffuse Correlation Spectroscopy to Cerebral Hemodynamics during Hypercapnia**

Abstract: We show through Monte Carlo simulations and in vivo recordings during hypercapnia that diffuse correlation spectroscopy is more sensitive to brain hemodynamics than continuous-wave NIRS, due to different physiological and physical contrasts.

27. Clancy et al. (2014). **Quantitative Evaluation of NIRS Probes and Imaging Protocol for Traumatic Brain Injury (TBI)**

Abstract: Realistic head models are used to assess the information content in regions of the brain relevant to monitoring traumatic brain injury patients with commercial NIRS probes, highlighting system variability and the need for better standardization.

28. Nemani et al. (2014). **Monte Carlo Based Simulation of Sensitivity Curvature for Evaluating Optimal Probe Geometry**

Abstract: Probe geometry can significantly influence the performances of functional near-infrared spectroscopy applications. This in silico work presents a novel approach for probe placement optimization based on the minimization of sensitivity curvature.

29. Jelzow et al. (2014). **Two-Layer Analysis of Time-Domain Functional NIRS Measurements**

Abstract: Oxy- and deoxyhemoglobin concentration changes for two layers were reconstructed by a robust method based on moments of photon flight-time distributions. The method was validated on a phantom and applied to in-vivo functional activation studies.

30. Fantini (2014). **NIRS Brain Studies with a New Hemodynamic Model: Coherent Hemodynamics Spectroscopy and Functional Neuroimaging**

Abstract: A new hemodynamic model relates tissue hemoglobin concentration to blood volume, flow, and oxygen consumption. It affords a quantitative analysis of hemodynamic oscillations (Coherent Hemodynamics Spectroscopy) and transients in neuroimaging.

31. Kainerstorfer et al. (2014). **Coherent Hemodynamics Spectroscopy of the Vulnerable Brain of Hemodialysis Patients: a Cyclic Thigh-Cuff Inflation Protocol**

Abstract: We present a pilot clinical application of Coherent Hemodynamics Spectroscopy, a novel technique to investigate cerebral hemodynamics at the microcirculatory level. Hemodialysis patients featured a slower cerebral blood flow than healthy controls.

32. Sassaroli et al. (2014). **Optical Study of the Cerebral Microcirculation with Coherent Hemodynamics Spectroscopy: a Paced Breathing Protocol**

Abstract: We applied a novel method, Coherent Hemodynamics Spectroscopy, to study the cerebral microcirculation using hemodynamic oscillations. We report microvascular transit times, blood volume, and autoregulation measurements on eleven healthy subjects.

33. Strait et al. (2014). **Reliability of NIRS-based BCIs: a placebo-controlled replication and reanalysis of brainput**

Abstract: Previously, we contributed to the development of a brain-computer interface (BCI), Brainput, using functional near infrared spectroscopy (NIRS). Initially Brainput was found to improve performance on a human-robot team task by adapting a robot's autonomy using NIRS-based classifications of the user's multitasking states [15, 16]. However, the failure to find any performance improvements in a follow-up study prompted reinvestigation of the original system via a reanalysis of Brainput's signal processing on a larger NIRS dataset and a placebo-controlled replication using random (instead of NIRS-based) state classifications. This reinvestigation revealed confounds in the original study responsible for the initial performance improvements, thus indicating that further work in signal processing is necessary to achieve reliable NIRS-based BCIs.

34. Tempest et al. (2014). **Prefrontal Cortex Haemodynamics and Affective Responses during Exercise: A Multi-Channel Near Infrared Spectroscopy Study**

Abstract: The dose-response effects of the intensity of exercise upon the potential regulation (through top-down processes) of affective (pleasure-displeasure) responses in the prefrontal cortex during an incremental exercise protocol have not been explored. This study examined the functional capacity of the prefrontal cortex (reflected by haemodynamics using near infrared spectroscopy) and affective responses during exercise at different intensities. Participants completed an incremental cycling exercise test to exhaustion. Changes (Δ) in oxygenation (O2Hb), deoxygenation (HHb), blood volume (tHb) and haemoglobin difference (HbDiff) were measured from bilateral dorsal and ventral prefrontal areas. Affective responses were measured every minute during exercise. Data were extracted at intensities standardised to: below ventilatory threshold, at ventilatory threshold, respiratory compensation point and the end of exercise. During exercise at intensities from ventilatory threshold to respiratory compensation point, ΔO2Hb, ΔHbDiff and ΔtHb were greater in mostly ventral than dorsal regions. From the respiratory compensation point to the end of exercise, ΔO2Hb remained stable and ΔHbDiff declined in dorsal regions. As the intensity increased above the ventilatory threshold, inverse associations between affective responses and oxygenation in (a) all regions of the left hemisphere and (b) lateral (dorsal and ventral) regions followed by the midline (ventral) region in the right hemisphere were observed. Differential activation patterns occur within the prefrontal cortex and are associated with affective responses during cycling exercise.

35. Zhang et al. (2014). **Twenty-four-hour ambulatory recording of cerebral hemodynamics, systemic hemodynamics, electrocardiography, and actigraphy during people's daily activities**

Abstract: The feasibility and utility of wearable 24-h multimodality neuromonitoring during daily activities are demonstrated. We have developed a fourth-generation ambulatory near infrared spectroscopy device, namely NINscan 4. NINscan 4 enables recording of brain function (via cerebral hemodynamics), systemic hemodynamics, electrocardiography, and actigraphy simultaneously and continuously for up to 24 h at 250-Hz sampling rate, during (and with minor restriction to) daily activities. We present initial 24-h human subject test results, with example analysis including (1) comparison of cerebral perfusion and oxygenation changes during wakefulness and sleep over a 24-h period and (2) capturing of hemodynamic changes prior, during and after sudden waken up in the night during sleep. These results demonstrate the first ambulatory 24-h cerebral and systemic hemodynamics monitoring, and its unique advantages including long-term data collection and analysis capability, ability to catch unpredictable transient events during activities of daily living, as well as coregistered multimodality analysis capabilities. These results also demonstrate that NINscan 4's motion artifact at 1-g head movement is smaller than physiological hemodynamic fluctuations during motionless sleep. The broader potential of this technology is also discussed.

36. Gallegos-Ayala et al. (2014). **Brain communication in a completely locked-in patient using bedside near-infrared spectroscopy**

Abstract: - not abstract available -

37. Lollgen et al. (2014). **Significant oxygen desaturation during aeromedical retrieval is common in infants younger than 6 weeks**

Abstract: Background and aims: Premature and term infants frequently require aeromedical transport. Little is known about oxygenation and safety during flight in infants < 6 months. Aims: We compared the incidence of desaturation SpO2 < 94% among preterm and term infants up to a postnatal age of 6 months, exposed to inflight hypobaric hypoxia. Methods: Retrospective recordings of continuous transcutaneous oxygen saturation monitoring in infants < 6 months, without supplemental oxygen undergoing aeromedical retrieval by NETS

NSW from January 2010 to December 2011 were examined. Modality and duration of transport, cabin pressure altitude (CPA) and indication for retrieval were recorded. Results: 112 infants < 6 months were transported via fixed or rotary wing aircraft. 32.1% showed significant oxygen desaturation < 94% during flight (36% of premature, 32.6% of < 1 week, 44.4% of < 6 week, 18% of < 3 month, 16% of 3–6 month old infants). Median lowest saturation was 95% (range, 45–100%), 94.5% (range, 60–98%) in preterm, 95% (range, 83–100%) in < 1 week, 95% (range, 83–100%) in < 6 week, 97% (range, 45–100%) in < 3 month, 98% (range 96–100%) in 3–6 month old infants. SpO2 normalized to ≥ 94% with oxygen supplementation or at lower CPA. Conclusions: One in three infants < 6 weeks of age desaturated to SpO2 < 94% during aeromedical retrieval compared to one in five in infants older than 6 weeks. This was more likely if congenital cardiac or respiratory disease were associated. However, air travel seems to be safe in this age group if oxygen supplementation is readily available.

38. Hong et al. (2014). **State-space models of impulse hemodynamic responses over motor, somatosensory, and visual cortices**

Abstract: THE PAPER PRESENTS STATE SPACE MODELS OF THE HEMODYNAMIC RESPONSE (HR) OF FNIRS TO AN IMPULSE STIMULUS IN THREE BRAIN REGIONS: motor cortex (MC), somatosensory cortex (SC), and visual cortex (VC). Nineteen healthy subjects were examined. For each cortex, three impulse HRs experimentally obtained were averaged. The averaged signal was converted to a state space equation by using the subspace method. The activation peak and the undershoot peak of the oxy-hemoglobin (HbO) in MC are noticeably higher than those in SC and VC. The time-to-peaks of the HbO in three brain regions are almost the same (about 6.76 76 ± 0.2 s). The time to undershoot peak in VC is the largest among three. The HbO decreases in the early stage (~0.46 s) in MC and VC, but it is not so in SC. These findings were well described with the developed state space equations. Another advantage of the proposed method is its easy applicability in generating the expected HR to arbitrary stimuli in an online (or real-time) imaging. Experimental results are demonstrated.

39. Strait et al. (2014). **Using functional near infrared spectroscopy to measure moral decision-making: effects of agency, emotional value, and monetary incentive**

Abstract: The prefrontal cortex (PFC) has been investigated extensively with functional magnetic resonance imaging (fMRI) and identified as a neural substrate central to emotion regulation and decision-making, particularly in the context of utilitarian moral dilemmas. However, there are two important limitations to prior work: (1) fMRI imposes strict constraints on the physical environment of the participant and (2) experimental manipulations have yet to consider the role of agency and personal incentive on both brain-based and behavioral correlates. To address the first limitation, we investigated functional near infrared spectroscopy (NIRS), which showed it was a potential alternative to fMRI for observing the decision-making processes in a less-constrained environment [1]. To address the second, we examined the role of agency in deciding moral and non-moral dilemmas and whether the influences can be further modulated by way of monetary incentives. Our findings show that all three factors exert influences on both behavioral and neural metrics. In particular, emotional value increases, whereas incentive decreases, prefrontal hemodynamic activity. Moreover, agency interacts with both emotional value and incentive, further polarizing the behavioral and neural metrics with regard to human patients.

40. Heger et al. (2014). **Continuous affective states recognition using functional near infrared spectroscopy**

Abstract: Monitoring the affective states of a person can be highly relevant for numerous disciplines, including adaptive user interfaces, entertainment, ergonomics, medicine and therapy. In many situations, the affective state of a user is not easily observable from outside by audio or video, but may be identified by a brain-computer interface (BCI). Functional near-infrared spectroscopy (fNIRS) is a brain imaging modality gaining rising

attention in the BCI community. However, fNIRS emotion recognition studies have only analyzed stimulus-locked effects. For realistic human-machine interaction scenarios, the point of time of an emotion-triggering event and the time span of an affective state are unknown. In this paper, we investigate a BCI that monitors the affective states of the user continuously over time (i.e. asynchronous BCI). In our study, fNRIS signals from eight subjects have been recorded at eight prefrontal locations in response to three different classes of affect induction by emotional audio-visual stimuli plus a neutral class. Our system evaluates short windows of 5 s length to continuously recognize affective states. We analyze hemodynamic responses, present a careful evaluation of binary classification tasks, compare time-domain and wavelet-based signal features, and investigate classification accuracies over time.

41. Mirelman et al. (2014). **Increased frontal brain activation during walking while dual tasking: an fNIRS study in healthy young adults**

Abstract: Background: Accumulating evidence suggests that gait is influenced by higher order cognitive and cortical control mechanisms. Recently, several studies used functional near infrared spectroscopy (fNIRS) to examine brain activity during walking, demonstrating increased oxygenated hemoglobin (HbO2) levels in the frontal cortex during walking while subjects completed a verbal cognitive task. It is, however, still unclear whether this increase in activation was related to verbalization, if the response was specific to gait, or if it would also be observed during standing, a different motor control task. The aim of this study was to investigate whether an increase in frontal activation is specific to dual tasking during walking. Methods: Twenty-three healthy young adults (mean 30.9 ± 3.7 yrs, 13 females) were assessed using an electronic walkway. Frontal brain activation was assessed using an fNIRS system consisting of two probes placed on the forehead of the subjects. Assessments included: walking in a self-selected speed; walking while counting forward; walking while serially subtracting 7s (Walking+S7); and standing while serially subtracting 7s (Standing+S7). Data was collected from 5 walks of 30 meters in each condition. Twenty seconds of quiet standing before each walk served as baseline frontal lobe activity. Repeated Measures Analysis of Variance (RM ANOVA) tested for differences between the conditions. Results: Significant differences were observed in HbO2 levels between all conditions ($p = 0.007$). HbO2 levels appeared to be graded; walking alone demonstrated the lowest levels of HbO2 followed by walking+counting condition ($p = 0.03$) followed by Walking+S7 condition significantly increased compared to the two other walking conditions ($p < 0.01$). No significant differences in HbO2 levels were observed between usual walking and the standing condition ($p = 0.38$) or between standing with or without serial subtraction ($p = 0.76$). Conclusions: This study provides direct evidence that dual tasking during walking is associated with frontal brain activation in healthy young adults. The observed changes are apparently not a response to the verbalization of words and are related to the cognitive load during gait.

42. Bakhsheshi et al. (2014). **Monitoring brain temperature by time-resolved near-infrared spectroscopy: pilot study**

Abstract: Mild hypothermia (HT 32°C–33°C) is an effective neuroprotective strategy for a variety of acute brain injuries. However, the wide clinical adaptation of HT 32–33°C has been hampered by the lack of a reliable noninvasive method for measuring brain temperature, since core measurements have been shown to not always reflect brain temperature. The goal of this work was to develop a noninvasive optical technique for measuring brain temperature that exploits both the temperature dependency of water absorption and the high concentration of water in brain (80%–90%). Specifically, we demonstrate the potential of time-resolved near-infrared spectroscopy (TR-NIRS) to measure temperature in tissue-mimicking phantoms (in vitro) and deep brain tissue (in vivo) during heating and cooling, respectively. For deep brain tissue temperature monitoring, experiments were conducted on newborn piglets wherein hypothermia was induced by gradual whole body cooling. Brain temperature was concomitantly measured by TR-NIRS and a thermocouple probe implanted in the brain. Our proposed TR-NIRS method was able to measure the temperature of tissue-mimicking phantoms and brain tissues with a correlation of 0.82 and 0.66 to temperature measured with a thermometer, respectively.

The mean difference between the TR-NIRS and thermometer measurements was 0.15°C±1.1°C for the in vitro experiments and 0.5°C±1.6°C for the in vivo measurements.

43. Yoshida et al. (2014). **Brain activity during the flow experience: A functional near-infrared spectroscopy study**

Abstract: Flow is the holistic experience felt when an individual acts with total involvement. Although flow is likely associated with many functions of the prefrontal cortex (PFC), such as attention, emotion, and reward processing, no study has directly investigated the activity of the PFC during flow. The objective of this study was to examine activity in the PFC during the flow state using functional near-infrared spectroscopy (fNIRS). Twenty right-handed university students performed a video game task under conditions designed to induce psychological states of flow and boredom. During each task and when completing the flow state scale for occupational tasks, change in oxygenated hemoglobin (oxy-Hb) concentration in frontal brain regions was measured using fNIRS. During the flow condition, oxy-Hb concentration was significantly increased in the right and left ventrolateral prefrontal cortex. Oxy-Hb concentration tended to decrease in the boredom condition. There was a significant increase in oxy-Hb concentration in the right and left dorsolateral prefrontal cortex, right and left frontal pole areas, and left ventrolateral PFC when participants were completing the flow state scale after performing the task in the flow condition. In conclusion, flow is associated with activity of the PFC, and may therefore be associated with functions such as cognition, emotion, maintenance of internal goals, and reward processing.

44. Diop et al. (2014). **Improved light collection and wavelet de-noising enable quantification of cerebral blood flow and oxygen metabolism by a low-cost, off-the-shelf spectrometer**

Abstract: Broadband continuous-wave near-infrared spectroscopy (CW-NIRS) is an attractive alternative to time-resolved and frequency-domain techniques for quantifying cerebral blood flow (CBF) and oxygen metabolism in newborns. However, efficient light collection is critical to broadband CW-NIRS since only a small fraction of the injected light emerges from any given area of the scalp. Light collection is typically improved by optimizing the contact area between the detection system and the skin by means of light guides with large detection surface. Since the form-factor of these light guides do not match the entrance of commercial spectrometers, which are usually equipped with a narrow slit to improve their spectral resolution, broadband NIRS spectrometers are typically custom-built. Nonetheless, off-the-shelf spectrometers have attractive advantages compared to custom-made units, such as low cost, small footprint, and wide availability. We demonstrate that off-the-shelf spectrometers can be easily converted into suitable instruments for deep tissue spectroscopy by improving light collection, while maintaining good spectral resolution, and reducing measurement noise. The ability of this approach to provide reliable cerebral hemodynamics was illustrated in a piglet by measuring CBF and oxygen metabolism under different anesthetic regimens.

45. Wutzler et al. (2014). **Acute Decrease of Cerebral Oxygen Saturation during Rapid Ventricular and Supraventricular Rhythm: A Pilot Study**

Abstract: Background: Monitoring of cerebral tissue oxygen saturation (SctO2) reflects cerebral microcirculation. We sought to characterize the decrease in SctO2 during supraventricular tachycardia (SVT) and ventricular tachycardia (VT) in adults. Methods: Twenty patients (mean age: 46.3 ± 18.1 years, 40% men) were included. Rapid atrial and ventricular pacing (200/min) was used as a model for VT and SVT. Near-infrared spectroscopy (NIRS) was used to measure SctO2. Results: Atrial stimulation decreased right ($P = 0.014$) and left ($P = 0.019$) hemispheric SctO2 compared to baseline. Ventricular stimulation also decreased right ($P < 0.001$) and left ($P < 0.001$) hemispheric SctO2. A negative correlation between age and minimal value under stimulation was found for atrial (right SctO2 $r = –0.641$, $P = 0.034$; left SctO2 $r = –0.694$, $P = 0.018$) and ventricular pacing (right SctO2 $r = –0.564$, $P = 0.01$; left SctO2 $r = –0.604$, $P = 0.005$). A positive correlation was found between left

ventricular ejection fraction (LVEF) and minimal value under ventricular stimulation (right SctO2 r = 0.567, P = 0.009; left SctO2 r = 0.471, P = 0.036). Conclusion: Cerebral perfusion decreased during simulated SVT and VT and is influenced by age and LVEF. Clinicians can consider NIRS monitoring in patients during ablation procedures and in critical care. NIRS may especially be appropriate for the elderly and for patients with impaired LVEF.

46. Manfredini et al. (2014). **Reliability of the Vascular Claudication Reporting in Diabetic Patients With Peripheral Arterial Disease - A Study With Near-Infrared Spectroscopy**

Abstract: We evaluated whether altered reporting of ischemic symptoms occurs in diabetic patients with peripheral arterial disease (PAD) and stable claudication. Patients (n = 152) with claudication were enrolled (120 males; mean age: 71.0 ± 8.6 years): 74 with diabetes (DM-PAD) and 78 without (DMfree-PAD). The degree of muscle oxygenation at symptom onset and maximal speed (Smax) during an incremental treadmill test was recorded at the gastrocnemius by near-infrared spectroscopy (NIRS) and quantified by area under the curve of oxygenated hemoglobin (AUC-Hbo2) and area under the curve of differential hemoglobin (AUC-dHb). The DM-PAD and DMfree-PAD showed similar exercise capacities inversely correlated with the degree of muscle oxygenation but significantly lower values of AUC-Hbo2 and AUC-dHb for DM-PAD at symptom onset and Smax (−356 vs −122 and −1200 vs −359, P < .0001). During a NIRS-assisted test, the report of claudication in the presence of diabetes was delayed, occurring at a lower degree of oxygenation than in patients with PAD only, with potential implications for testing, functional staging, and balance disorders.

47. Ikeuchi et al. (2014). **Evaluating "Cosmetic Therapy" by Using Near-Infrared Spectroscopy**

Abstract: This study examined the effect of cosmetic therapy on frontal lobe activation as revealed by topographic near-infrared spectroscopy (NIRS). We evaluated emotional responses to a photograph of a face with/without makeup by 22 healthy female volunteers (mean age, 52 ± 10.5 years). The results of the first-round analysis showed a significant increase of oxy-Hb in the frontal lobe area when the subject looked at a photograph of herself made up as compared to not made up. In a later round of analysis, we divided the subjects into 2 groups having contrasting scores on the Profile of Mood States-Short Form Japanese version. One group was classed as "high vigor" (a common standard pattern) and the other as "low vigor" (depression-tendency pattern). The made-up/not made-up difference did not have any effect on the oxy-Hb level in the frontal lobe in the high vigor group. In contrast, makeup produced a significant increase in the oxy-Hb level over a wide frontal area in the low vigor group, which indicated widespread frontal lobe activation. This result indicates a beneficial effect of cosmetic therapy on the brain function of patients with depression and/ or dementia.

48. Eggebrecht et al. (2014). **Mapping distributed brain function and networks with diffuse optical tomography**

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.

49. Ogawa et al. (2014). **Relationship between working memory performance and neural activation measured using near-infrared spectroscopy**

Abstract: Background: Working memory (WM) is a key function for various cognitive processes. Near-infrared spectroscopy (NIRS) is a powerful technique for noninvasive functional imaging. However, a study has yet to be published on the application of NIRS for evaluating WM performance. The objective was to evaluate NIRS for measuring WM performance. Methods: Subjects were trained to perform a visuospatial WM task. Eight channels on the lateral prefrontal cortex were analyzed. We asked the following three questions: (1) Does WM performance correlate with NIRS signal amplitudes? (2) What are the differences in NIRS amplitudes between correct- and incorrect-WM tasks? (3) Is there a correlation between WM performance and NIRS amplitudes in only correct-WM tasks? Results: NIRS activation in all channels correlated with WM performance ($P < 0.05$). There was a statistically significant difference ($P < 0.05$) in seven channels between NIRS amplitude in correct- and incorrect-WM tasks. NIRS activation of the delay time averaged with only correct-WM tasks, correlated with WM performance in six channels ($P < 0.05$). Conclusions: Subjects with better WM performance have higher levels of oxyhemoglobin activation compared with control trials in the WM delay time, and our results suggest that NIRS will be useful for measuring the WM performance.

50. Widge et al. (2014). **Affective brain-computer interfaces as enabling technology for responsive psychiatric stimulation**

Abstract: There is a pressing clinical need for responsive neurostimulators, which sense a patient's brain activity and deliver targeted electrical stimulation to suppress unwanted symptoms. This is particularly true in psychiatric illness, where symptoms can fluctuate throughout the day. Affective BCIs, which decode emotional experience from neural activity, are a candidate control signal for responsive stimulators targeting the limbic circuit. Present affective decoders, however, cannot yet distinguish pathologic from healthy emotional extremes. Indiscriminate stimulus delivery would reduce quality of life and may be actively harmful. We argue that the key to overcoming this limitation is to specifically decode volition, in particular the patient's intention to experience emotional regulation. Those emotion-regulation signals already exist in prefrontal cortex (PFC), and could be extracted with relatively simple BCI algorithms. We describe preliminary data from an animal model of PFC-controlled limbic brain stimulation and discuss next steps for pre-clinical testing and possible translation.

51. Schneider et al. (2014). **Comparison of four near-infrared spectroscopy devices shows that they are only suitable for monitoring cerebral oxygenation trends in preterm infants**

Abstract: Aim: Measuring cerebral oxygenation using near-infrared spectroscopy (NIRS) has taken on an increasingly important role in the field of neonatology. Several companies have already developed commercial devices, and more publications are reporting absolute boundary values or percentiles for neonates. We compared four commercially used devices to discover whether they provided consistent results in the same patients. Methods: We recruited nine preterm infants and tested them for 2 h, using sensors from two different devices. The measurements were carried out six times on each child, so that all four devices were compared with each other. A total of 54 measurements were conducted. The following devices were compared: the NIRO 200 (Hamamatsu Photonics K.K), the INVOS 5100c (Somanetics), the Fore-Sight (CAS Med.) and the SenSmart X-100 (NONIN). Results: The cerebral tissue oxygenation data yielded by the individual devices differed significantly from each other, ranging from a minimum difference of 2.93% to a maximum difference of 12.66%. Conclusion: The commercially available NIRS devices showed highly significant differences in local cerebral tissue oxygenation levels, to the extent that the industry cannot agree on uniform and reproducible standards. Therefore, NIRS should only be used for trend measurements in preterm infants.

52. Hatta et al. (2014). **Developmental trajectories of verbal and visuospatial abilities in healthy older adults: Comparison of the hemisphere asymmetry reduction in older adults model and the right hemi-ageing model**

Abstract: Two models of cognitive ageing, the hemisphere asymmetry reduction in older adults (HAROLD) model and the right hemi-ageing model, were compared based upon the verbal memory and visuospatial task performance of 338 elderly participants. Comparison of the developmental trajectories for four age groups (50s, 60s, 70s and 80s) supported the HAROLD model, but not the right hemi-ageing model. Performance differences between the verbal memory and visuospatial tasks in the earlier age groups decreased in the later age groups. There was a sex difference in the cognitive-decline trajectories for verbal and visuospatial task performance after the 50s.

53. Fujii et al. (2014). **Does oral care contribute to brain activation?: One case of functional near-infrared spectroscopy study in patients with a persistent disturbance of consciousness**

Abstract: We used functional near-infrared spectroscopy (fNIRS) to measure cerebral blood flow during oral care in a patient with persistent disturbance of consciousness. We experienced that cerebral blood flow to frontal area increased during oral care, suggesting that oral care may have a potential role in rehabilitation for the brain.

54. Zhang et al. (2014). **Studying hemispheric lateralization during a Stroop task through near-infrared spectroscopy-based connectivity**

Abstract: Near-infrared spectroscopy (NIRS) is a developing and promising functional brain imaging technology. Developing data analysis methods to effectively extract meaningful information from collected data is the major bottleneck in popularizing this technology. In this study, we measured hemodynamic activity of the prefrontal cortex (PFC) during a color-word matching Stroop task using NIRS. Hemispheric lateralization was examined by employing traditional activation and novel NIRS-based connectivity analyses simultaneously. Wavelet transform coherence was used to assess intrahemispheric functional connectivity. Spearman correlation analysis was used to examine the relationship between behavioral performance and activation/functional connectivity, respectively. In agreement with activation analysis, functional connectivity analysis revealed leftward lateralization for the Stroop effect and correlation with behavioral performance. However, functional connectivity was more sensitive than activation for identifying hemispheric lateralization. Granger causality was used to evaluate the effective connectivity between hemispheres. The results showed increased information flow from the left to the right hemispheres for the incongruent versus the neutral task, indicating a leading role of the left PFC. This study demonstrates that the NIRS-based connectivity can reveal the functional architecture of the brain more comprehensively than traditional activation, helping to better utilize the advantages of NIRS.

55. Payzieva et al. (2014). **NIRS Study of the Effects of Computerized Brain Training Games for Cognitive Rehabilitation of Major Depressive Disorder Patients in Remission: A Pilot Study**

Abstract: We used functional Near-Infrared Spectroscopy (fNIRS) to estimate brain activity in Major Depressive Disorder (MDD) patients (in remission), while they played a computerized brain training games for cognitive rehabilitation. MDD is characterized by marked deterioration in affect as well as significant impairment in cognitive function. It was found, that depressed patients showed long-lasting impaired cognitive performance on cognitive demanding tasks despite significant improvement in the depression symptoms. Previous studies have shown that video games can improve cognitive functions. But assessment was made only with cognitive tests. The main objective of this research was to study the effects of brain training games on cognitive functions of MDD patients in remission with objective instrumental NIRS method. Tissue oxygen saturation (StO2) and absolute concentrations of oxyhemoglobin ([O2Hb]), deoxyhemoglobin ([HHb]) and total

hemoglobin ([tHb]) were measured by functional near-infrared spectroscopy (fNIRS) - Oxyprem (BORL, Zurich, Switzerland). Preliminary results are discussed.

56. Viola et al. (2014). **The increased distensibility of the wall of cerebral arterial network may play a role in the pathogenic mechanism of migraine headache**

Abstract: The aim was to evaluate whether patients with episodic migraine with (MA+) and without aura (MA−), during the interictal period of migraine would have an altered distensibility of the wall of cerebral arterial network and whether it would play a role in migraine headache. To evaluate the distensibility of the wall of cerebral arterial network, we measured the time-delay in milliseconds (ms) between the R-wave of an electrocardiogram and the arterial pulse wave of cerebral microcirculation (R-APWCMtd) on the frontal cortex detected by near-infrared spectroscopy (NIRS) in 10 patients with MA+ (age 39.5 ± 12.2 years), in 10 with MA− (age 40.3 ± 10.2 years), according to ICHD-3 criteria 2012, during the interictal period of migraine, and in 15 age-, sex- and height-matched healthy control subjects. The patients with migraine had a significantly longer R-APWCMtd than the control subjects $F = 13.4$, $p < 0.001$: MA+:+38.3 ms; MA−:+34.7 ms indicating an increased distensibility of the wall of cerebral arterial network. In multiple regression analysis, R-APWCMtd was significantly associated with migraine ($R\ 2 = 0.50$, $p < 0.0001$) but not with age, gender, height, migraine attack frequency and disease duration. The increased distensibility leads to an increased flow pulsatility into intracranial dural meningeal vessels that may lead to a mechanical stimulation of the nociceptors that innervate the dural vasculature. This condition may play a role in promoting the sensitization of trigeminovascular afferents and sterile inflammation within the dura mater that are fundamental to the pathogenesis of migraine headache.

57. Ganesan et al. (2014). **Effect of Blood Flow Restriction on Tissue Oxygenation during Knee Extension**

Abstract: PURPOSE: Time-Resolved Near Infrared Spectroscopy (TR-NIRS) was used to quantify tissue oxy- and deoxy-hemoglobin concentrations ([HbO2], [HbR]), and O2 saturation (stO2) in the oblique fibers of the vastus medialis muscle (VMO) and brain prefrontal cortex (PFC) during knee extension with and without blood flow restriction (BFR). METHODS: Six young healthy males performed three sets of knee extensions on a dynamometer (50% 1 RM), separated by 90 sec rest periods, in three conditions: 1) until fatigue without BFR (Fatigue); 2) until fatigue with BFR (100 mm Hg cuff constriction around thigh, BFR); 3) same number of repetitions from condition 2, without BFR (Matched). Each condition was performed on a separate visit. RESULTS: BFR was associated with higher VMO [HbR] (rest 1: 57.8 µM BFR vs. 35.0 µM Matched, $p < 0.0001$) and a significantly lower stO2 during recovery periods between sets (7.5 - 11.2 % lower than non-BFR conditions for rest 1 and 2, $p < 0.0001$). Using a piecewise linear spline method, a spike in [HbR] was observed before the onset of HbR clearance during recovery, causing HbR clearance to begin at a higher concentration (BFR: 81 µM vs. Matched: 62 µM, $p = 0.029$). [HbO2] kinetics during recovery were also affected by BFR, with longer duration (BFR: 51 s, Matched: 31 s, $p = 0.047$) but lower rate of increase (BFR: 58 µM/min, Matched: 89 µM/min, $p = 0.004$) during recovery. In the PFC, BFR was associated with increased [HbR], diminished increase in [HbO2], and higher subjective exertion. CONCLUSIONS: These findings yield insight into possible physiological mechanisms of BFR, and suggest a role of TR-NIRS in monitoring and optimization of BFR exercise on an individual basis.

58. Lewis et al. (2014). **A Continuous Correlation Between Intracranial Pressure and Cerebral Blood Flow Velocity Reflects Cerebral Autoregulation Impairment During Intracranial Pressure Plateau Waves**

Abstract: BACKGROUND: In the healthy brain, small oscillations in intracranial pressure (ICP) occur synchronously with those in cerebral blood volume (CBV), cerebrovascular resistance, and consequently cerebral

blood flow velocity (CBFV). Previous work has shown that the usual synchrony between ICP and CBFV is lost during intracranial hypertension. Moreover, a continuously computed measure of the ICP/CBFV association (Fix index) was a more sensitive predictor of outcome after traumatic brain injury (TBI) than a measure of autoregulation (Mx index). In the current study we computed Fix during ICP plateau waves, to observe its behavior during a defined period of cerebrovascular vasodilatation. METHODS: Twenty-nine recordings of arterial blood pressure (ABP), ICP, and CBFV taken during ICP plateau waves were obtained from the Addenbrooke's hospital TBI database. Raw data was filtered prior to computing Mx and Fix according to previously published methods. Analyzed data was segmented into three phases (pre, peak, and post), and a median value of each parameter was stored for analysis. RESULTS: ICP increased from a median of 22-44 mmHg before falling to 19 mmHg. Both Mx and Fix responded to the increase in ICP, with Mx trending toward +1, while Fix trended toward -1. Mx and Fix correlated significantly (Spearman's R = -0.89, $p < 0.000001$), however, Fix spanned a greater range than Mx. A plot of Mx and Fix against CPP showed a plateau (Mx) or trough (Fix) consistent with a zone of "optimal CPP". CONCLUSIONS: The Fix index can identify complete loss of cerebral autoregulation as the point at which the normally positive CBF/CBV correlation is reversed. Both CBF and CBV can be monitored noninvasively using near-infrared spectroscopy (NIRS), suggesting that a noninvasive method of monitoring autoregulation using only NIRS may be possible.

59. Shimizu et al. (2014). **Prefrontal Activation during Cognitive Processes in Aging: A Near-Infrared Spectroscopy Study**

Abstract: Purpose: Cognitive processing generally deteriorates as people age. Recent neuroimaging studies have shown that the prefrontal cortex (PFC) is involved in human-specific behavior, such as preparing for future actions and prospective memory; hence, the PFC may be voluntarily activated even during the “resting” condition that precedes task execution. The purpose of the present study was to investigate changes in voluntary pre-task activation as a result of aging using a paradigm that includes a longer intertrial interval (e.g., 30 sec) than has been used in previous studies. Methods: A total of 120 cognitively normal adults (young: 60, old: 60) participated in this near-infrared spectroscopy (NIRS) study. All subjects performed 6 repetitions of the working memory task, which included a 30 sec resting period and a 28.8 sec task period. The resting period was divided into baseline and pre-task (preT) periods, and the task period was divided into early easy task (eT) and late difficult task (dT) periods. We then normalized the data, analyzed the magnitude of task-related NIRS responses in each period and compared the results between groups using an analysis of variance test. Results: Statistical analyses revealed a significant interaction between group × optode location × period, in which hemodynamic responses in the PFC during the preT period were smaller in the elderly in than young adults. By contrast, during the task period, the hemodynamic responses were higher in the lateral PFC in the elderly than in young adults. Spearman's rank correlation analysis showed a positive correlation between hemodynamic changes during the preT period in the PFC and correct answer ratios in both groups. Conclusions: These findings suggest that more pre-task activation in the anterior PFC is related to better cognitive performance in humans. Thus, a reduction in this activation might partly explain cognitive decline in the elderly.

60. Kocaoglu et al. (2014). **Foreseeing the danger in the beach chair position: Are standard measurement methods reliable?**

Abstract: Purpose: The aim of this study is to show whether peripheral perfusion monitoring methods reflect central perfusion during shoulder arthroscopy at beach chair position. We hypothesized that mean arterial pressure (MAP), central heart rate (CHR) and peripheral oxygenation (SaO2) measurements individually will not parallel cerebral oximetry measurements by near-infrared spectroscopy (NIRS). Methods: Between 2011 and 2012, 53 patients who had arthroscopic rotator cuff repair surgery in the beach chair position were enrolled prospectively. Median ages of the patients were 58 (range 42–68) years. The regional cerebral oxygen saturation value of each hemisphere was continuously monitored by the use of NIRS. MAP, CHR, SaO2 and both hemispheric cerebral oxygen saturation values were recorded at six time periods peri-operatively. Correlation

and differences between parameters were evaluated. Results: Cerebral oxygen saturation of right hemisphere was dropped >20 % in 28.3 and 45.3 % of the patients. At left hemisphere, cerebral oxygen saturation was dropped >20 % in 20.8 and 43.4 % of the patients. Peripheral saturation values were statistically different from cerebral saturation values ($p < 0.001$). On the other hand, there was a correlation between cerebral saturation and MAP values ($p < 0.05$). Conclusion: Cerebral oximetry by NIRS may prove useful as a monitor for cerebral ischaemia. In the absence of NIRS, CHR can partially detect abnormalities but not trustable, and MAP is the most reliable method for monitoring.

61. Fabricius-Bjerre et al. (2014). **Reduced cerebral oxygen–carbohydrate index during endotracheal intubation in vascular surgical patients**

Abstract: Brain activation reduces balance between cerebral consumption of oxygen versus carbohydrate as expressed by the so-called cerebral oxygen-carbohydrate-index (OCI). We evaluated whether preparation for surgery, anaesthesia including tracheal intubation and surgery affect OCI. In patients undergoing aortic surgery, arterial to internal jugular venous (a-v) concentration differences for oxygen versus lactate and glucose were determined from before anaesthesia to when the patient left the recovery room. Intravenous anaesthesia was supplemented with thoracic epidural anaesthesia for open aortic surgery (n = 5) and infiltration with bupivacaine for endovascular procedures (n = 14). The a-v difference for O2 decreased throughout anaesthesia and in the recovery room (1·6 ± 1·9 versus 3·2 ± 0·8 mmol l−1, mean ± SD), and while a-v glucose decreased during surgery and into the recovery (0·4 ± 0·2 versus 0·7 ± 0·2 mmol l−1, P<0·05), a-v lactate did not change significantly (0·03 ± 0·16 versus −0·03 ± 0·09 mmol l−1). Thus, OCI decreased from 5·2 ± 1·8 before induction of anaesthesia to 3·2 ± 1·0 following tracheal intubation (P<0·05) because of the decrease in a-v O2 with a recovery for OCI to 4·6 ± 1·4 during surgery and to 5·6 ± 1·7 in the recovery room. In conclusion, preparation for surgery and tracheal intubation decrease OCI that recovers during surgery under the influence of sensory blockade.

62. Abramo et al. (2014). **Innovative Application of Cerebral rSO2 Monitoring During Shunt Tap in Pediatric Ventricular Malfunctioning Shunts**

Abstract: Objective: This study aimed to determine the reliability and potential application of cerebral regional tissue oxygenation (rSO2) monitoring in malfunctioning ventricular shunts during tap. Methods: This is a prospective case series using convenience sample in subjects with confirmed malfunctioning shunt who had left and right cerebral rSO2 monitoring every 5 seconds before, during, and 1 hour after shunt tap. Results: Ninety-four subjects had cerebral rSO2 monitoring. Sixty-three subjects had proximal malfunctions, and 31 subjects had distal shunt malfunctions. The intrasubject's cerebral rSO2 trend and variability at pretap, during, and posttap times were highly correlated. Overall, the average rSO2 is lower in pretap as compared with posttap. Left cerebral rSO2 had lower means and larger SD as compared with right cerebral rSO2. Left pretap and posttap cerebral rSO2 variability was significantly associated with the location of shunt malfunction regardless of pretap, during, or posttap periods ($P < 0.001$), whereas right rSO2 variability was not predictive for malfunction location. Left cerebral rSO2 variability showed utility for identifying the location of malfunction with area under the receiver operating characteristic curve equal to 0.8. Conclusions: Reliable cerebral rSO2 readings before, during, and after shunt tap were demonstrated. Left cerebral rSO2 changes from before to after shunt tap were more predictive for shunt malfunction location than right cerebral rSO2 changes. Observing cerebral rSO2 changes in relationship to shunt tap represents a potential surrogate in measuring cerebral pressures and blood flow changes after cerebral spinal fluid drainage. Significantly greater cerebral rSO2 changes occur for distal malfunction versus proximal malfunction after shunt tap, indicating its potential as an adjunct tool for detecting shunt malfunction type.

63. Shah et al. (2014). **An integrated framework for joint HRF and drift estimation and HbO/HbR signal improvement in fNIRS data**

Abstract: Non-parametric hemodynamic response function (HRF) estimation in functional near-infrared spectroscopy (fNIRS) data plays an important role when investigating the temporal dynamics of a brain region response during activations. Assuming the drift arising from both physical and physiological effects in fNIRS data is Lipschitz continuous; a novel algorithm for joint HRF and drift estimation is derived in this paper. The proposed algorithm estimates the HRF by applying a first order differencing to the fNIRS time series samples in order to remove the drift effect. An estimate of the drift is then obtained using a wavelet thresholding technique applied to the residuals generated by removing the estimated induced activation response from the fNIRS time-series. It is shown that the proposed HRF estimator is pN consistent whereas the estimator of the drift is asymptotically optimal. The de-drifted fNIRS oxygenated (HbO) and deoxygenated (HbR) hemoglobin responses are then obtained by removing the corresponding estimated drifts from the fNIRS time-series. Its performance is assessed using both simulated and real fNIRS data sets. The application results reveal that the proposed joint HRF and drift estimation method is efficient both computationally and in terms of accuracy. In comparison to traditional model based methods used for HRF estimation, the proposed novel method avoids the selection of a model to remove the drift component. As a result, the proposed method finds an optimal estimate of the fNIRS drift and offers a modelfree approach to de-drift the HbO/HbR responses.

64. Shaul et al. (2014). **Cerebral Blood Volume and Vasodilation are Independently Diminished by Aging and Hypertension: A Near InfraRed Spectroscopy Study**

Abstract: Background: Senescent changes in brain microvascular circulation may cause or contribute to age-related cognitive decline. Such changes are promoted partly by aging, but also by chronic hypertension, a leading treatable cause of cognitive decline. Objectives: We aimed to non-invasively detect in vivo the senescent changes in brain microvascular circulation associated with age and hypertension, and inquired whether decrements driven by aging would be exacerbated by chronic hypertension. Methods: In this longitudinal study, absolute near infrared spectroscopy (NIRS) was used to quantify in vivo cerebral blood volume (CBV) and assess the hemodynamic response to a hypercapnic respiratory challenge in normotensive Wistar-Kyoto (WKY) and spontaneous-hypertensive (SHR) rats. The impact of age and hypertension were evaluated by repeating these measurements on the same animals at 4- and 16-months of age. Results: CBV decreased markedly with age in both strains, from 4.5 ± 0.2 to 2.6 ± 0.1 ml/100g tissue, on average. Chronic hypertension, however, did not significantly exacerbate this age-related decrease in CBV (−48.1 ± 3.7% in WKYs versus −53.3 ± 5.4% in SHRs). In contrast, vasoreactivity was already impaired in the young hypertensive rats (ΔVMR 0.017 ± 0.014 in young SHRs versus 0.042 ± 0.005 in young WKYs) and further worsened by middle-age (ΔVMR 0.011 ± 0.017 middle-aged SHRs). Conclusion: Whereas a decrease in brain blood volume correlated with age but not hypertension, vasodilatory capacity was diminished due to hypertension but did not appear affected by age alone. The ability of absolute NIRS to distinguish between such senescent changes in brain (micro)vascular circulation in life may allow early detection and intervention to preserve cerebrovascular health with age.

65. Sawamura et al. (2014). **Active inhibition of task-irrelevant sounds and its neural basis in patients with attention deficits after traumatic brain injury**

Abstract: Primary objective: To examine active inhibition of irrelevant stimuli and evaluate its neural basis using functional near infrared spectroscopy in patients with attention deficits after traumatic brain injury (TBI). Research design: Case control study. Methods and procedures: Ten patients with TBI and 10 healthy control subjects participated in this study. The Paced Auditory Serial Addition Test (PASAT) was performed with (distracting PASAT) and without (PASAT) distracting Japanese kana phonetic characters presented between each number. A block design was used. Subjects alternately performed each task three times. Main outcomes and results: Healthy controls performed better than patients with TBI on both the tasks. When performing the

PASAT, healthy controls showed significant activity in every region of interest except the right lateral prefrontal cortex (PFC), but patients with TBI showed significant activity only in the left anterior PFC and left lateral PFC. When performing the distracting PASAT, the right lateral PFC was active in healthy controls, but not in patients with TBI. Conclusion: These results confirm that patients with moderate-to-severe TBI were affected by distractors that influenced order processing. It is suggested that the working memory of patients with TBI was affected by distracting stimuli, whereas that of healthy individuals was not.

66. Selvaperumal et al. (2014). **Design and Development of Two Channel Portable Near Infrared Spectroscopy System for Studies of Cerebral Oxygenation in Prefrontal Cortex of Human Brain**

Abstract: Functional near infrared spectroscopy is a noninvasive, non harmful, low cost and safe optical technique that can be used to study the functional activities in the human brain. This paper describes the development of two channel Near InfraRed Spectroscopy (NIRS) system and the results of the cerebral oxygenation changes during the different cognitive tasks. The objective of the study is to design, develop a portable non-invasive continuous wave NIRS system with dual wave length for determining the hemoglobin content of the blood chromophores during different activities of the prefrontal cortex of the brain. The two channel NIRS system designed and it was tested with 20 healthy, ie.,15 males and 5 females with an average age group of 21±2.25, they were given a 2 different mental tasks such as sequential subtraction (mathematical task) and spot the difference (Visuo-spatial task) and their Oxy & de-Oxy hemoglobin concentration was measured which showed more changes during the task period when compared to relaxation in both left and right part of pre-frontal cortex.

67. Faull et al. (2014). **Cerebrovascular responses during rowing: Do circadian rhythms explain morning and afternoon performance differences?**

Abstract: The purpose of this study was to characterize cerebrovascular responses to rowing exercise, investigating whether their diurnal variation might explain performance differences across a day. Twelve male rowers completed incremental rowing exercise and a 2000-m ergometer time trial at 07:00 h and 16:00 h, 1 week apart, while middle cerebral artery velocity (MCAv), cerebral (prefrontal), and muscular (vastus lateralis) tissue oxygenation and hemoglobin volume (via near-infrared spectroscopy), heart rate, and pressure of end-tidal CO2 (PETCO2) were recorded. MCAv was 20–25% above resting levels (68 ± 12 cm/s) during submaximal and maximal exercise intensities, despite PETCO2 being reduced during maximal efforts (down ~ 0.5–0.8 kPa); thus revealing a different perfusion profile to the inverted-U observed in other exercise modes. The afternoon time trial was 3.4 s faster (95% confidence interval 0.9–5.8 s) and mean power output 3.2% higher (337 vs 347 W; $P = 0.04$), in conjunction with similar exercise-induced elevations in MCAv ($P = 0.60$) and reductions in cerebral oxygenation (TOI) ($P = 0.12$). At the muscle, afternoon trials involved similar oxygen extraction (HHb volume and TOI) albeit from a relatively lower total Hb volume ($P < 0.01$). In conclusion, rowing performance was better in the afternoon, but not in conjunction with differences in MCAv or exercise-induced differences in cerebral oxygenation.

68. Miyamoto et al. (2014). **Variational Inference With ARD Prior for NIRS Diffuse Optical Tomography**

Abstract: Diffuse optical tomography (DOT) reconstructs 3-D tomographic images of brain activities from observations by near-infrared spectroscopy (NIRS) that is formulated as an ill-posed inverse problem. This brief presents a method for NIRS DOT based on a hierarchical Bayesian approach introducing the automatic relevance determination prior and the variational Bayes technique. Although the sparseness of the estimation strongly depends on the hyperparameters, in general, our method has less dependency on the hyperparameters. We confirm through numerical experiments that a schematic phase diagram of sparseness with respect to the

hyperparameters has two regions: in one region hyperparameters give sparse solutions and in the other they give dense ones. The experimental results are supported by our theoretical analyses in simple cases.

69. Pandin et al. (2014). **Monitoring Brain and Spinal Cord Metabolism and Function**

Abstract: Monitoring the metabolism and function of the central nervous system not only is an old idea but also is a topic that is of increasing interest to the technological evolution. Beside the optimization of cerebral and spinal cord perfusion and the preservation of vasoreactivity to ensure the viability of cerebral tissues and structures, we want to know more and more about the real intimate situation of these organs in real time at the patient's bedside. To this end, several tracks have been explored during the two last decades, leading to the development of numerous concepts and the conception of various monitoring systems. One of the main problems is to characterize the respective strong points and weaknesses of those ones and to conclude regarding their individual relevance and value in current clinical practice. It is more and more clear that the combination of different categories of monitoring is a way to try to find the most valuable technological compromise, to increase the chance of prediction or of early detection of intercurrent deleterious events corresponding to the concept of multimodality. The intraoperative period and the intensive care goals and targets are appreciably different. This is the reason for the attempt to define different and distinct sets of goals and targets for the intraoperative anesthetic setting and for the intensive care unit.

70. Lanfranconi et al. (2014). **Near Infrared Spectroscopy (NIRS) as a New Non-Invasive Tool to Detect Oxidative Skeletal Muscle Impairment in Children Survived to Acute Lymphoblastic Leukaemia**

Abstract: Background: Separating out the effects of cancer and treatment between central and peripheral components of the O2 delivery chain should be of interest to clinicians for longitudinal evaluation of potential functional impairment in order to set appropriate individually tailored training/rehabilitation programmes. We propose a non-invasive method (NIRS, near infrared spectroscopy) to be used in routine clinical practice to evaluate a potential impairment of skeletal muscle oxidative capacity during exercise in children previously diagnosed with acute lymphoblastic leukaemia (ALL). The purpose of this study was to evaluate the capacity of skeletal muscle to extract O2 in 10 children diagnosed with ALL, 1 year after the end of malignancy treatment, compared to a control group matched for gender and age (mean±SD = 7.8±1.5 and 7.3±1.4 years, respectively). Methods and Findings: Participants underwent an incremental exercise test on a treadmill until exhaustion. Oxygen uptake (), heart rate (HR), and tissue oxygenation status (Δ[HHb]) of the vastus lateralis muscle evaluated by NIRS, were measured. The results showed that, in children with ALL, a significant linear regression was found by plotting vs Δ[HHb] both measured at peak of exercise. In children with ALL, the slope of the HR vs linear response (during sub-maximal and peak work rates) was negatively correlated with the peak value of Δ[HHb]. Conclusions: The present study proves that the NIRS technique allows us to identify large inter-individual differences in levels of impairment in muscle O2 extraction in children with ALL. The outcome of these findings is variable and may reflect either muscle atrophy due to lack of use or, in the most severe cases, an undiagnosed myopathy.

71. Shin et al. (2014). **Multiclass classification of hemodynamic responses for performance improvement of functional near-infrared spectroscopy-based brain–computer interface**

Abstract: We improved the performance of a functional near-infrared spectroscopy (fNIRS)-based brain–computer interface based on relatively short task duration and multiclass classification. A custom-built eight-channel fNIRS system was used over the motor cortex areas in both hemispheres to measure the hemodynamic responses evoked by four different motor tasks (overt execution of arm lifting and knee extension for both sides) instead of finger tapping. The hemodynamic responses were classified using the naive Bayes classifier. Among the mean, max, slope, variance, and median of the signal amplitude and the time lag of the signal, several signal

features are chosen to obtain highest classification accuracy. Ten runs of threefold cross-validation were conducted, which yielded classification accuracies of 87.1%±2.4% to 95.5%±2.4% , 77.5%±1.9% to 92.4%±3.2% , and 73.8%±3.5% to 91.5%±1.4% for the binary, ternary, and quaternary classifications, respectively. Eight seconds of task duration for obtaining sufficient quaternary classification accuracy was suggested. The bit transfer rate per minute (BPM) based on the quaternary classification accuracy was investigated. A BPM can be achieved from 2.81 to 5.40 bits/min.

72. Perdue et al. (2014). **Extraction of heart rate from functional near-infrared spectroscopy in infants**

Abstract: Changes in heart rate are a useful physiological measure in infant studies. We present an algorithm for calculating the heart rate (HR) from oxyhemoglobin pulsation in functional near-infrared spectroscopy (fNIRS) signals. The algorithm is applied to data collected from 10 infants, and the HR derived from the fNIRS signals is compared against the HR as calculated by electrocardiography. We show high agreement between the two HR signals for all infants (r>0.90), and also compare stimulus-related HR responses as measured by the two methods and find good agreement despite high levels of movement in the infants. This algorithm can be used to measure changes in HR in infants participating in fNIRS studies without the need for additional HR sensors.

73. Takei et al. (2014). **Near-infrared spectroscopic study of frontopolar activation during face-to-face conversation in major depressive disorder and bipolar disorder**

Abstract: Major depressive disorder (MDD) and bipolar disorder (BD) patients show speech characteristics that vary greatly according to mood state. In a previous study, we found impaired temporal and right inferior frontal gyrus (IFG) activation in schizophrenia during face-to-face conversation; no study had, however, previously investigated mood disorders during face-to-face conversation. Here, we investigated frontal and temporal lobe activation during conversation in patients with MDD and BD. Frontal and temporal lobe activation was measured using near-infrared spectroscopy (NIRS) in 29 patients with MDD, 31 patients with BD, and 31 normal controls (NC). We compared continuous activation and rapid change of activation with talk/listen phase changes during the conversation and analyzed the correlation between these indices and clinical variables. Both the MDD and BD groups showed decreased continuous activation in the left dorsolateral prefrontal (DLPFC) and left frontopolar cortices (FPCs); they also showed decreased rapid change in bilateral FPC activation. In the MDD group, the rapid change of activation was positively correlated with Global Assessment of Functioning (GAF) scores. In the BD group, continuous activation was negatively correlated with age of onset. These results indicate that frontal activation during conversation decreases in both MDD and BD. However, both continuous activation and rapid change may reflect the pathophysiological character of MDD and BD; in particular, the reduced amount of rapid change in the right FPC may be related to impaired adaptive ability in MDD.

74. Dunaev et al. (2014). **Investigating tissue respiration and skin microhaemocirculation under adaptive changes and the synchronization of blood flow and oxygen saturation rhythms**

Abstract: Multi-functional laser non-invasive diagnostic systems allow the study of a number of microcirculatory parameters, including index of blood microcirculation (Im) (by laser Doppler flowmetry, LDF) and oxygen saturation (StO2) of skin tissue (by tissue reflectance oximetry, TRO). This research aimed to use such a system to investigate the synchronization of microvascular blood flow and oxygen saturation rhythms under normal and adaptive change conditions. Studies were conducted on eight healthy volunteers of 21–49 years. These volunteers were observed between one and six months, totalling 422 basic tests (3 min each). Measurements were performed on the palmar surface of the right middle finger and the lower forearm's medial surface. Rhythmic oscillations of LDF and TRO were studied using wavelet analysis. Combined tissue oxygen consumption data for all volunteers during 'adaptive changes' increased relative to normal conditions with and without arteriovenous anastomoses. Data analysis revealed resonance and synchronized rhythms in

microvascular blood flow and oxygen saturation as an adaptive change in myogenic oscillation (vasomotion) resulting from exercise and possibly psychoemotional stress. Synchronization of myogenic rhythms during adaptive changes may lead to increased oxygen consumption as a result of increased microvascular blood flow velocity.

75. Schweiger et al. (2014). **The Toast++ software suite for forward and inverse modeling in optical tomography**

Abstract: We present the Toast++ open-source software environment for solving the forward and inverse problems in diffuse optical tomography (DOT). The software suite consists of a set of libraries to simulate near-infrared light propagation in highly scattering media with complex boundaries and heterogeneous internal parameter distribution, based on a finite-element solver. Steady-state, time- and frequency-domain data acquisition systems can be modeled. The forward solver is implemented in C++ and supports performance acceleration with parallelization for shared and distributed memory architectures, as well as graphics processing computation. Building on the numerical forward solver, Toast++ contains model-based iterative inverse solvers for reconstructing the volume distribution of absorption and scattering parameters from boundary measurements of light transmission. A range of regularization methods are provided, including the possibility of incorporating prior knowledge of internal structure. The user can link to the Toast++ libraries either directly to compile application programs for DOT, or make use of the included MATLAB and PYTHON bindings to generate script-based solutions. This approach allows rapid prototyping and provides a rich toolset in both environments for debugging, testing, and visualization.

76. Periyasamy et al. (2014). **Monte Carlo simulation of light transport in turbid medium with embedded object—spherical, cylindrical, ellipsoidal, or cuboidal objects embedded within multilayered tissues**

Abstract: Monte Carlo modeling of light transport in multilayered tissue (MCML) is modified to incorporate objects of various shapes (sphere, ellipsoid, cylinder, or cuboid) with a refractive-index mismatched boundary. These geometries would be useful for modeling lymph nodes, tumors, blood vessels, capillaries, bones, the head, and other body parts. Mesh-based Monte Carlo (MMC) has also been used to compare the results from the MCML with embedded objects (MCML-EO). Our simulation assumes a realistic tissue model and can also handle the transmission/reflection at the object-tissue boundary due to the mismatch of the refractive index. Simulation of MCML-EO takes a few seconds, whereas MMC takes nearly an hour for the same geometry and optical properties. Contour plots of fluence distribution from MCML-EO and MMC correlate well. This study assists one to decide on the tool to use for modeling light propagation in biological tissue with objects of regular shapes embedded in it. For irregular inhomogeneity in the model (tissue), MMC has to be used. If the embedded objects (inhomogeneity) are of regular geometry (shapes), then MCML-EO is a better option, as simulations like Raman scattering, fluorescent imaging, and optical coherence tomography are currently possible only with MCML.

77. Sun et al. (2014). **Diffuser-aided time-domain diffuse optical imaging: a phantom study**

Abstract: We present the first experimental results of time-resolved diffuser-aided diffuse optical imaging (DADOI) method in this paper. A self-manufactured diffuser plate was inserted between the optode and the surface of a scattering medium. The diffuser was utilized to enhance the multiple scattering that destroys the image information for baseline measurement of turbid medium. Therefore, the abnormality can be detected with the modified optical density calculation. The time-domain DADOI method can provide better imaging contrast and simpler imaging than the conventional diffuse optical tomography measurement. Besides, it also reveals rich depth information with temporal responses. Therefore, the DADOI offers a great potential to detect the breast tumor and chemotherapy monitoring in clinical diagnosis.

78. Teplov et al. (2014). **Fast vascular component of cortical spreading depression revealed in rats by blood pulsation imaging**

Abstract: Cortical spreading depression (CSD) is a slowly propagating wave of depolarization of neurons and glia and has a less characterized vascular component. CSD is a commonly used phenomenon to test new methods of live brain imaging. Application of a blood pulsations imaging (BPI) technique to study of CSD induced with high-potassium solution in rat cortex allowed us to visualize for the first time the novel vascular component of a CSD wave. In our study, this wave component propagated in the limited part of the cortex along the bow-shaped trajectory in sharp contrast with concentric development of CSD measured by concurrently applied optical intrinsic signal (OIS) imaging technique. It was associated with a significant increase of the blood pulsations amplitude (BPA), started with a delay of 20 to 90 s comparing to signal measured with OIS, and propagated 40% faster than OIS signal. These findings suggest that the BPA and slower change of the cerebral blood volume are not directly related to each other even though both characterize the same vascular system. Our study indicates that the BPI technique could be used for characterization of the new pulsatile vascular component of CSDs in animal models of migraine, stroke, and brain trauma.

79. Lee et al. (2014). **Noninvasive optical cytochrome c oxidase redox state measurements using diffuse optical spectroscopy**

Abstract: A major need exists for methods to assess organ oxidative metabolic states in vivo. By contrasting the responses to cyanide (CN) poisoning versus hemorrhage in animal models, we demonstrate that diffuse optical spectroscopy (DOS) can detect cytochrome c oxidase (CcO) redox states. Intermittent decreases in inspired O 2 from 100% to 21% were applied before, during, and after CN poisoning, hemorrhage, and resuscitation in rabbits. Continuous DOS measurements of total hemoglobin, oxyhemoglobin, deoxyhemoglobin, and oxidized and reduced CcO from muscle were obtained. Rabbit hemorrhage was accomplished with stepwise removal of blood, followed by blood resuscitation. CN treated rabbits received 0.166 mg/min NaCN infusion. During hemorrhage, CcO redox state became reduced concurrently with decreases in oxyhemoglobin, resulting from reduced tissue oxygen delivery and hypoxia. In contrast, during CN infusion, CcO redox state decreased while oxyhemoglobin concentration increased due to CN binding and reduction of CcO with resultant inhibition of the electron transport chain. Spectral absorption similarities between hemoglobin and CcO make noninvasive spectroscopic distinction of CcO redox states difficult. By contrasting physiological perturbations of CN poisoning versus hemorrhage, we demonstrate that DOS measured CcO redox state changes are decoupled from hemoglobin concentration measurement changes.

80. 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.

81. Mozumder et al. (2014). **Compensation of modeling errors due to unknown domain boundary in diffuse optical tomography**

Abstract: Diffuse optical tomography is a highly unstable problem with respect to modeling and measurement errors. During clinical measurements, the body shape is not always known, and an approximate model domain has to be employed. The use of an incorrect model domain can, however, lead to significant artifacts in the reconstructed images. Recently, the Bayesian approximation error theory has been proposed to handle model-based errors. In this work, the feasibility of the Bayesian approximation error approach to compensate for modeling errors due to unknown body shape is investigated. The approach is tested with simulations. The

results show that the Bayesian approximation error method can be used to reduce artifacts in reconstructed images due to unknown domain shape.

Publications from the BORL, Zurich

82. Mata Pavia et al. (2014). **Single-Photon Avalanche Diode Imagers Applied to Near-Infrared Imaging**

Abstract: Single-photon avalanche diodes (SPADs) can be integrated into large pixel arrays. The aim of this paper is to present a view on how these imagers change the paradigm of wide-field near-infrared imaging (NIRI). Thanks to the large number of pixels that they offer and to their advanced time-resolved measurement capabilities, new approaches in the image reconstruction can be applied. A SPAD imager was integrated in a NIRI setup to demonstrate how it can improve spatial resolution in reconstructed images. The SPAD imager has a time resolution of 97 ps and a picosecond laser source with an average output power of 3 mW was employed. The large amount of data produced by this new setup could not directly be analyzed with state-of-the art image reconstruction algorithms. Therefore a new theoretical framework was developed. Simulations show that millimetric resolution is achievable with this setup. Experimental results have demonstrated that a resolution of at least 5 mm is possible with the current setup. A discussion about how different characteristics of the SPAD imagers affect the NIRI measurements is presented and possible future improvements are introduced.

83. Holper et al. (2014). **fNIRS derived hemodynamic signals and electrodermal responses in a sequential risk-taking task**

Abstract: The study measured cortical hemodynamic signals and peripheral correlates of decision makers during a dynamic risky task, the Just One More task (JOM), in which the risky decision entails choosing whether to incrementally increase accumulated earnings at the risk of ruin (going bust ending up with nothing). Twenty subjects participated in multiple instantiations of this task in which the probability of ruin and size of the stakes varied. Physiological correlates were simultaneously quantified by functional near-infrared spectroscopy (fNIRS) over dorsolateral prefrontal cortex (DLPFC) and electrodermal activity (EDA). First, in the task decision phase (i.e., when subjects are contemplating options before making a choice) probability of ruin had a dissociating effect on fNIRS and EDA. fNIRS derived DLPFC hemodynamic signals reflected a subjective value signal, correlating positively with individual risk attitude. Contrary, EDA reflected the probability of ruin in terms of a common affective measure, irrespective of individuals′ risk attitude. Second, during the task outcome phase (i.e., the time after subjects have made a choice and observed the outcomes) fNIRS and EDA revealed opposite patterns. While fNIRS derived DLPFC hemodynamic signals were larger in response to gains, EDA signals were larger in response to losses; both patterns were statistically independent of individual risk attitude. Lastly, fNIRS derived DLPFC hemodynamic signals in the decision phase correlated positively with the mean round earnings, providing a measure of the quality of the individual decision-making performance. Together with the positive correlation with individual risk attitude, our findings indicate that fNIRS signals, but not EDA, could be taken as a useful method for studying individual risk attitude and task performance in dynamic risky decision-making.