DCS publications on PubMed: January 1, 2022 - April 30, 2022

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Methodology. Searches were made in PubMed constraining the search period between January 1, 2022 and April 30, 2022. These were later processed for readability but no records were otherwise added or removed. In the preparation of this file, the following searches have been executed:

- diffuse correlation spectroscopy

Non-Invasive Blood Flow Speed Measurement Using Optics.

Zhang AC, Lo YH.
Sensors (Basel). 2022 Jan 25;22(3):897.
doi: 10.3390/s22030897.

Non-invasive measurement of the arterial blood speed gives important health information such as cardio output and blood supplies to vital organs. The magnitude and change in arterial blood speed are key indicators of the health conditions and development and progression of diseases. We demonstrated a simple technique to directly measure the blood flow speed in main arteries based on the diffused light model. The concept is demonstrated with a phantom that uses intralipid hydrogel to model the biological tissue and an embedded glass tube with flowing human blood to model the blood vessel. The correlation function of the measured photocurrent was used to find the electrical field correlation function via the Siegert relation. We have shown that the characteristic decorrelation rate (i.e., the inverse of the decoherent time) is linearly proportional to the blood speed and independent of the tube diameter. This striking property can be explained by an approximate analytic solution for the diffused light equation in the regime where the convective flow is the dominating factor for decorrelation. As a result, we have demonstrated a non-invasive method of measuring arterial blood speed without any prior knowledge or assumption about the geometric or mechanic properties of the blood vessels.

FPGA Correlator for Applications in Embedded Smart Devices.

Moore CH, Lin W.
Biosensors (Basel). 2022 Apr 12;12(4):236.
doi: 10.3390/bios12040236.

Correlation has a variety of applications that require signal processing. However, it is computationally intensive, and software correlators require high-performance processors for real-time data analysis. This is a challenge for embedded devices because of the limitation of computing resources. Hardware correlators that use Field Programmable Gate Array (FPGA) technology can significantly boost computational power and bridge the gap between the need for high-performance computing and the limited processing power available in embedded devices. This paper presents a detailed FPGA-based correlator design at the register level along with the open-source Very High-Speed Integrated Circuit Hardware Description Language (VHDL) code. It includes base modules for linear and multi-tau correlators of varying sizes. Every module implements a simple and unified data interface for easy integration with standard and publicly available FPGA modules. Eighty-lag linear and multi-tau correlators were built for validation of the design. Three input data sets-constant signal, pulse signal, and sine signal-were used to test the accuracy of the correlators.

The results from the FPGA correlators were compared against the outputs of equivalent software correlators and validated with the corresponding theoretical values. The FPGA correlators returned results identical to those from the software references for all tested data sets and were proven to be equivalent to their software counterparts. Their computation speed is at least 85,000 times faster than the software correlators running on a Xilinx MicroBlaze processor. The FPGA correlator can be easily implemented, especially on System on a Chip (SoC) integrated circuits that have processor cores and FPGA fabric. It is the ideal component for device-on-chip solutions in biosensing.

Development of a Monte Carlo-wave model to simulate time domain diffuse correlation spectroscopy measurements from first principles.

Cheng X, Chen H, Sie EJ, Marsili F, Boas DA.

J Biomed Opt. 2022 Feb;27(8):083009.
doi: 10.1117/1.JBO.27.8.083009.

SIGNIFICANCE: Diffuse correlation spectroscopy (DCS) is an optical technique that measures blood flow non-invasively and continuously. The time-domain (TD) variant of DCS, namely, TD-DCS has demonstrated a potential to improve brain depth sensitivity and to distinguish superficial from deeper blood flow by utilizing pulsed laser sources and a gating strategy to select photons with different pathlengths within the scattering tissue using a single source-detector separation. A quantitative tool to predict the performance of TD-DCS that can be compared with traditional continuous wave DCS (CW-DCS) currently does not exist but is crucial to provide guidance for the continued development and application of these DCS systems. AIMS: We aim to establish a model to simulate TD-DCS measurements from first principles, which enables analysis of the impact of measurement noise that can be utilized to quantify the performance for any particular TD-DCS system and measurement geometry. APPROACH: We have integrated the Monte Carlo simulation describing photon scattering in biological tissue with the wave model that calculates the speckle intensity fluctuations due to tissue dynamics to simulate TD-DCS measurements from first principles. RESULTS: Our model is capable of simulating photon counts received at the detector as a function of time for both CW-DCS and TD-DCS measurements. The effects of the laser coherence, instrument response function, detector gate delay, gate width, intrinsic noise arising from speckle statistics, and shot noise are incorporated in the model. We have demonstrated the ability of our model to simulate TD-DCS measurements under different conditions, and the use of our model to compare the performance of TD-DCS and CW-DCS under a few typical measurement conditions. CONCLUSION: We have established a Monte Carlo-Wave model that is capable of simulating CW-DCS and TD-DCS measurements from first principles. In our exploration of the parameter space, we could not find realistic measurement conditions under which TD-DCS outperformed CW-DCS. However, the parameter space for the optimization of the contrast to noise ratio of TD-DCS is large and complex, so our results do not imply that TD-DCS cannot indeed outperform CW-DCS under different conditions. We made our code available publicly for others in the field to find use cases favorable to TD-DCS. TD-DCS also provides a promising way to measure deep brain tissue dynamics using a short source-detector separation, which will benefit the development of technologies including high density DCS systems and image reconstruction using a limited number of source-detector pairs.

Erratum: Estimating intracranial pressure using pulsatile cerebral blood flow measured with diffuse correlation spectroscopy: erratum.

Ruesch A, Yang J, Schmitt S, Acharya D, Smith MA, Kainerstorfer JM.

Biomed Opt Express. 2022 Jan 12;13(2):710-712.
doi: 10.1364/BOE.452731. eCollection 2022 Feb 1.

Erratum for Biomed Opt Express. 2020 Feb 19;11(3):1462-1476.

Evaluation of Local Skeletal Muscle Blood Flow in Manipulative Therapy by Diffuse Correlation Spectroscopy.

Matsuda Y, Nakabayashi M, Suzuki T, Zhang S, Ichinose M, Ono Y.

Front Bioeng Biotechnol. 2022 Jan 11;9:800051.
doi: 10.3389/fbioe.2021.800051. eCollection 2021.

Manipulative therapy (MT) is applied to motor organs through a therapist's hands. Although MT has been utilized in various medical treatments based on its potential role for increasing the blood flow to the local muscle, a quantitative validation of local muscle blood flow in MT remains challenging due to the lack of appropriate bedside evaluation techniques. Therefore, we investigated changes in the local blood flow to the muscle undergoing MT by employing diffuse correlation spectroscopy, a portable and emerging optical measurement technology that non-invasively measures blood flow in deep tissues. This study investigated the changes in blood flow, heart rate, blood pressure, and autonomic nervous activity in the trapezius muscle through MT application in 30 volunteers without neck and shoulder injury. Five minutes of MT significantly increased the median local blood flow relative to that of the pre-MT period ($p < 0.05$). The post-MT local blood flow increase was significantly higher in the MT condition than in the control condition, where participants remained still without receiving MT for the same time ($p < 0.05$). However, MT did not affect the heart rate, blood pressure, or cardiac autonomic nervous activity. The post-MT increase in muscle blood flow was significantly higher in the participants with muscle stiffness in the neck and shoulder regions than in those without ($p < 0.05$). These results suggest that MT could increase the local blood flow to the target skeletal muscle, with minimal effects on systemic circulatory function.

Open-source FlexNIRS: A low-cost, wireless and wearable cerebral health tracker.

Wu KC, Tamborini D, Renna M, Peruch A, Huang Y, Martin A, Kaya K, Starkweather Z, Zavriyev AI, Carp SA, Salat DH, Franceschini MA.

Neuroimage. 2022 Apr 19;256:119216.
doi: 10.1016/j.neuroimage.2022.119216. Online ahead of print.

Currently, there is great interest in making neuroimaging widely accessible and thus expanding the sampling population for better understanding and preventing diseases. The use of wearable health devices has skyrocketed in recent years, allowing continuous assessment of physiological parameters in patients and research cohorts. While most health wearables monitor the heart, lungs and skeletal muscles, devices targeting the brain are currently lacking. To promote brain health in the general population, we developed a novel, low-cost wireless cerebral oximeter called FlexNIRS. The device has 4 LEDs and 3 photodiode detectors arranged in a symmetric geometry, which allows for a self-calibrated multi-distance method to recover cerebral hemoglobin oxygenation (SO2) at a rate of 100Hz. The device is powered by a rechargeable battery and uses Bluetooth Low Energy (BLE) for wireless communication. We developed an Android application for portable data collection and real-time analysis and display. Characterization tests in phantoms and human participants show very low noise (noise-equivalent power <70 fW/vHz) and robustness of SO2 quantification in vivo. The estimated cost is on the order of $50/unit for 1000 units, and our goal is to share the device with the research community following an open-source model. The low cost, ease-of-use, smart-phone readiness, accurate SO2 quantification, real time data quality feedback, and long battery life make prolonged monitoring feasible in low resource settings, including typically medically underserved communities, and enable new community and telehealth applications.

Cerebral Blood Flow Hemispheric Asymmetry in Comatose Adults Receiving Extracorporeal Membrane Oxygenation.

Johnson TW, Dar IA, Donohue KL, Xu YY, Santiago E, Selioutski O, Marinescu MA, Maddox RK, Wu TT, Schifitto G, Gosev I, Choe R, Khan IR.
Front Neurosci. 2022 Apr 11;16:858404.
doi: 10.3389/fnins.2022.858404. eCollection 2022.

Peripheral veno-arterial extracorporeal membrane oxygenation (ECMO) artificially oxygenates and circulates blood retrograde from the femoral artery, potentially exposing the brain to asymmetric perfusion. Though ECMO patients frequently experience brain injury, neurologic exams and imaging are difficult to obtain. Diffuse correlation spectroscopy (DCS) non-invasively measures relative cerebral blood flow (rBF) at the bedside using an optical probe on each side of the forehead. In this study we observed interhemispheric rBF differences in response to mean arterial pressure (MAP) changes in adult ECMO recipients. We recruited 13 subjects aged 21-78 years (7 with cardiac arrest, 4 with acute heart failure, and 2 with acute respiratory distress syndrome). They were dichotomized via Glasgow Coma Scale Motor score (GCS-M) into comatose (GCS-M = 4; n = 4) and non-comatose (GCS-M > 4; n = 9) groups. Comatose patients had greater interhemispheric rBF asymmetry (ASYMrBF) vs. non-comatose patients over a range of MAP values (29 vs. 11%, p = 0.009). ASYMrBF in comatose patients resolved near a MAP range of 70-80 mmHg, while rBF remained symmetric through a wider MAP range in non-comatose patients. Correlations between post-oxygenator pCO2 or pH vs. ASYMrBF were significantly different between comatose and non-comatose groups. Our findings indicate that comatose patients are more likely to have asymmetric cerebral perfusion.

First-in-clinical application of a time-gated diffuse correlation spectroscopy system at 1064 nm using superconducting nanowire single photon detectors in a neuro intensive care unit.

Poon CS, Langri DS, Rinehart B, Rambo TM, Miller AJ, Foreman B, Sunar U.
Biomed Opt Express. 2022 Feb 7;13(3):1344-1356.
doi: 10.1364/BOE.448135. eCollection 2022 Mar 1.

Recently proposed time-gated diffuse correlation spectroscopy (TG-DCS) has significant advantages compared to conventional continuous wave (CW)-DCS, but it is still in an early stage and clinical capability has yet to be established. The main challenge for TG-DCS is the lower signal-to-noise ratio (SNR) when gating for the deeper traveling late photons. Longer wavelengths, such as 1064 nm have a smaller effective attenuation coefficient and a higher power threshold in humans, which significantly increases the SNR. Here, we demonstrate the clinical utility of TG-DCS at 1064 nm in a case study on a patient with severe traumatic brain injury admitted to the neuro-intensive care unit (neuroICU). We showed a significant correlation between TG-DCS early (? = 0.67) and late (? = 0.76) gated against invasive thermal diffusion flowmetry. We also analyzed TG-DCS at high temporal resolution (50 Hz) to elucidate pulsatile flow data. Overall, this study demonstrates the first clinical translation capability of the TG-DCS system at 1064 nm using a superconducting nanowire single-photon detector.

Complete head cerebral sensitivity mapping for diffuse correlation spectroscopy using subject-specific magnetic resonance imaging models.

Wu MM, Perdue K, Chan ST, Stephens KA, Deng B, Franceschini MA, Carp SA.
Biomed Opt Express. 2022 Feb 1;13(3):1131-1151.
doi: 10.1364/BOE.449046. eCollection 2022 Mar 1.

We characterize cerebral sensitivity across the entire adult human head for diffuse correlation spectroscopy, an optical technique increasingly used for bedside cerebral perfusion monitoring. Sixteen subject-specific magnetic resonance imaging-derived head models were used to identify high sensitivity regions by running Monte Carlo light propagation simulations at over eight hundred uniformly distributed locations on the head. Significant spatial variations in cerebral sensitivity, consistent across subjects, were found. We also identified correlates of such differences suitable for real-time assessment. These variations can be largely attributed to changes in extracerebral thickness and should be taken into account to optimize probe placement in experimental settings.

Cortical Spreading Depolarization, Blood Flow, and Cognitive Outcomes in a Closed Head Injury Mouse Model of Traumatic Brain Injury.

Mosley N, Chung JY, Jin G, Franceschini MA, Whalen MJ, Chung DY.

Neurocrit Care. 2022 Apr 4.
doi: 10.1007/s12028-022-01474-7. Online ahead of print.

BACKGROUND: Cortical spreading depolarizations (CSDs) are associated with worse outcomes in many forms of acute brain injury, including traumatic brain injury (TBI). Animal models could be helpful in developing new therapies or biomarkers to improve outcomes in survivors of TBI. Recently, investigators have observed CSDs in murine models of mild closed head injury (CHI). We designed the currently study to determine additional experimental conditions under which CSDs can be observed, from mild to relatively more severe TBI. METHODS: Adult male C57Bl/6J mice (8-14weeks old) were anesthetized with isoflurane and subjected to CHI with an 81-g weight drop from 152 or 183cm. CSDs were detected with minimally invasive visible light optical intrinsic signal imaging. Cerebral blood flow index (CBFi) was measured in the 152-cm drop height cohort using diffuse correlation spectroscopy at baseline before and 4min after CHI. Cognitive outcomes were assessed at 152- and 183-cm drop heights for the Morris water maze hidden platform, probe, and visible platform tests. RESULTS: CSDs occurred in 43% (n = 12 of 28) of 152-cm and 58% (n = 15 of 26) of 183-cm drop height CHI mice (p = 0.28). A lower baseline preinjury CBFi was associated with development of CSDs in CHI mice (1.50 0.07 10-7 CHI without CSD [CSD-] vs. 1.17 0.04 10-7 CHI with CSD [CSD+], p = 0.0001). Furthermore, in CHI mice that developed CSDs, the ratio of post-CHI to pre-CHI CBFi was lower in the hemisphere ipsilateral to a CSD compared with non-CSD hemispheres (0.19 0.07 less in the CSD hemisphere, p = 0.028). At a 152-cm drop height, there were no detectable differences between sham injured (n = 10), CHI CSD+ (n = 12), and CHI CSD- (n = 16) mice on Morris water maze testing at 4weeks. At a 183-cm drop height, CHI CSD+ mice had worse performance on the hidden platform test at 1-2weeks versus sham mice (n = 15 CHI CSD+, n = 9 sham, p = 0.045), but there was no appreciable differences compared with CHI CSD- mice (n = 11 CHI CSD-). CONCLUSIONS: The data suggest that a lower baseline cerebral blood flow prior to injury may contribute to the occurrence of a CSD. Furthermore, a CSD at the time of injury can be associated with worse cognitive outcome under the appropriate experimental conditions in a mouse CHI model of TBI.

Improving Infant Hydrocephalus Outcomes in Uganda: A Longitudinal Prospective Study Protocol for Predicting Developmental Outcomes and Identifying Patients at Risk for Early Treatment Failure after ETV/CPC.

Vadset TA, Rajaram A, Hsiao CH, Kemigisha Katungi M, Magombe J, Seruwu M, Kaaya Nsubuga B, Vyas R, Tatz J, Playter K, Nalule E, Natukwatsa D, Wabukoma M, Neri Perez LE, Mulondo R, Queally JT, Fenster A, Kulkarni AV, Schiff SJ, Grant PE, Mbabazi Kabachelor E, Warf BC, Sutin JDB, Lin PY.

Metabolites. 2022 Jan 14;12(1):78.
doi: 10.3390/metabo12010078.

Infant hydrocephalus poses a severe global health burden; 80% of cases occur in the developing world where patients have limited access to neurosurgical care. Surgical treatment combining endoscopic third ventriculostomy and choroid plexus cauterization (ETV/CPC), first practiced at CURE Children's Hospital of Uganda (CCHU), is as effective as standard ventriculoperitoneal shunt (VPS) placement while requiring fewer resources and less post-operative care. Although treatment focuses on controlling ventricle

size, this has little association with treatment failure or long-term outcome. This study aims to monitor the progression of hydrocephalus and treatment response, and investigate the association between cerebral physiology, brain growth, and neurodevelopmental outcomes following surgery. We will enroll 300 infants admitted to CCHU for treatment. All patients will receive pre/post-operative measurements of cerebral tissue oxygenation (SO2), cerebral blood flow (CBF), and cerebral metabolic rate of oxygen consumption (CMRO2) using frequency-domain near-infrared combined with diffuse correlation spectroscopies (FDNIRS-DCS). Infants will also receive brain imaging, to monitor tissue/ventricle volume, and neurodevelopmental assessments until two years of age. This study will provide a foundation for implementing cerebral physiological monitoring to establish evidence-based guidelines for hydrocephalus treatment. This paper outlines the protocol, clinical workflow, data management, and analysis plan of this international, multi-center trial.

Assessing cerebral blood flow, oxygenation and cytochrome c oxidase stability in preterm infants during the first 3days after birth.

Rajaram A, Milej D, Suwalski M, Kebaya L, Kewin M, Yip L, de Ribaupierre S, Han V, Diop M, Bhattacharya S, St Lawrence K.

Sci Rep. 2022 Jan 7;12(1):181.
doi: 10.1038/s41598-021-03830-7.

A major concern with preterm birth is the risk of neurodevelopmental disability. Poor cerebral circulation leading to periods of hypoxia is believed to play a significant role in the etiology of preterm brain injury, with the first three days of life considered the period when the brain is most vulnerable. This study focused on monitoring cerebral perfusion and metabolism during the first 72h after birth in preterm infants weighing less than 1500g. Brain monitoring was performed by combining hyperspectral near-infrared spectroscopy to assess oxygen saturation and the oxidation state of cytochrome c oxidase (oxCCO), with diffuse correlation spectroscopy to monitor cerebral blood flow (CBF). In seven of eight patients, oxCCO remained independent of CBF, indicating adequate oxygen delivery despite any fluctuations in cerebral hemodynamics. In the remaining infant, a significant correlation between CBF and oxCCO was found during the monitoring periods on days 1 and 3. This infant also had the lowest baseline CBF, suggesting the impact of CBF instabilities on metabolism depends on the level of blood supply to the brain. In summary, this study demonstrated for the first time how continuous perfusion and metabolic monitoring can be achieved, opening the possibility to investigate if CBF/oxCCO monitoring could help identify preterm infants at risk of brain injury.