FIU | Engineering & Computing

Department of Biomedical Engineering

GRADUATE RESEARCH DAY

SPRING 2025

DISCOVER | DESIGN | DEVELOP | DELIVER

DREAM, DISCOVER,
INSPIRE, INVIGORATE

FIU | Engineering & Computing

Department of Biomedical Engineering

The Department of Biomedical Engineering at Florida International University (FIU) located in Miami is committed to preparing ambitious students who want to combine their love of problem-solving with their desire to help others through this fascinating growing field that applies cutting-edge technologies and modern engineering techniques to improve healthcare.

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Florida International University | College of Engineering and Computing
Department of Biomedical Engineering
10555 West Flagler Street Suite EC 2600 Miami, FL 33174

GRADUATE RESEARCH DAY — Friday, March 14, 2025

The Biomedical Engineering Graduate Research Day showcases all the exciting research that our Biomedical Engineering graduate students are involved in. On Graduate Research Day, student researchers get the stage. It is a day-long opportunity for graduate students to gain valuable professional development experience, network with industry partners, present research, and learn about the research of others.

FIU Engineering & Computing
Department of Biomedical Engineering

14th Annual

Graduate Research Day
Friday, March 14, 2025

Room EC 2300

7:30 am
Breakfast

8:45 am – 9:00 am
Welcome Remarks and Snacks

9:00 am – 10:00 am
Seminar with Dr. Jessica P. Houston, Professor of Chemical & Materials Engineering, New Mexico State University

10:15 am – 10:30 am
Short Break

Panther Pit

10:30 am – 12:30 pm
Poster Presentations

12:30 pm – 1:30 pm
Lunch for Attendees

Room EC 2300

2:00 pm – 3:00 pm
Flash Talks

3:00 pm – 4:00 pm
Panel Discussion

4:00 pm – 4:30 pm
Closing Remarks & Awards Ceremony

MESSAGE FROM THE CHAIR

Today we celebrate your achievements. You serve as the backbone of our Department, and you continue to push us to new heights. We are proud of your hard work and dedication in advancing human knowledge and developing technologies that will transform the future of medicine. Research involves pushing the limits of our collective understanding, which requires inquisitiveness, resiliency, creativity, innovation, and intelligence.

The work that you present today demonstrates that you have the necessary attributes to conduct research at the highest level. The Graduate Research Day provides an opportunity to reflect on your accomplishments and showcase your work with pride.

As you move forward in your graduate education, continue motivating yourself and others around you to enhance your knowledge, remain inquisitive, and continue to grow in all aspects of learning.

Thank you to all who have worked to make this Graduate Research Day a success!

Best wishes for continued success,

Jorge Riera Diaz, Ph.D.

Interim Chair of Biomedical Engineering

KEYNOTE SPEAKER

APPLICATIONS OF FLUORESCENCE LIFETIME MEASUREMENTS IN FLOW CYTOMETRY

ABSTRACT: Methods for high throughput single-cell analyses have become quite complex over the last decade with emerging technologies that advance the speed of imaging and sorting as well as enhance the number of parameters that can be measured from a single cell. Many instruments, cytometers, or similar devices provide essential features about cells because optical measurements provide not only spatial but also temporal information about the intracellular environment. Time-resolved flow cytometry (TRFC) is one form of cytometry that captures temporal information about fluorescent molecules inside the cell. Such information does not rely on brightness and often correlates to signaling events, molecular movement, and dynamics of molecular interaction. Various TRFC technologies will be presented as well as applications that focus on metabolic mapping of tamoxifen resistant breast cancer cells using autofluorescence. Focus will also be placed on a chip-based cytometer that utilizes acoustic focusing for more ac-curate fluorescence lifetime measurements. The long-term impact of this work is to develop new tools that pro-vide more quantitative fluorescence information at the throughput of a flow cytometer.

Dr. Jessica P. Houston

Professor of Chemical & Materials Engineering, New Mexico State University

SHORT BIO: Dr. Jessica P. Houston is a Professor of Chemical & Materials Engineering at New Mexico State University (NMSU) in Las Cruces, NM. Her research includes flow cytometry instrument optimization, fluorescence dynamics, high-throughput systems, optofluidics, and fluorescence bioprobes. Dr. Houston has been at NMSU since 2009 where she first began her career in academia as an Assistant Professor. She came to NMSU after completing a 3-year Director's Postdoctoral Fellowship within the Bioscience Division at the Los Alamos National Laboratory, Los Alamos, NM (2006-2009). Dr. Houston provides service to a variety of scientific societies, boards, and advisory councils. She is President of ISAC (International Society for the Advancement of Cytometry, 2023-2026), Chair of ISAC Executive Committee, and serves on the council and as ex-officio of all 12 ISAC committees and numerous task forces and working groups. Additionally, Dr. Houston is Chair of the Conference on Imaging, Manipulation, and Analysis of Cells and Tissues for the SPIE Photonics West Congress. Her scientific contributions have been presented in high impact papers, proceedings, and chapters, as well as numerous conference abstracts and invited international and national symposia. She holds a patent on lifetime measurements with cytometry and as a faculty member teaches fluid mechanics, biomedical engineering, process control, and dynamics. In 2024 Dr. Houston became a Faculty Fulbright Scholar in Brazil at the University of Sao Paulo.

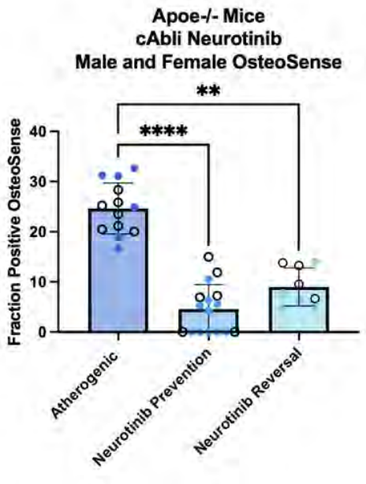
ORAL PRESENTATIONS

cAbl Tyrosine Kinase Inhibitor Neurotinib as a Target for Vascular Calcification

Authors: Ana Valentín Cabrera, Ana Fonseca, Mark Henderson, Juan Marugan, Alexander Agoulnik and Joshua Hutcheson

Faculty Advisor: Dr. Joshua Hutcheson

Vascular calcification contributes to the rupture of atherosclerotic plaques—the leading cause of heart attacks. No therapeutics exist to treat vascular calcification. cAbl is a non-receptor tyrosine kinase with many biological functions, including regulating endocytosis and membrane trafficking pathways associated with vascular calcification. Neurotinib, a selective cAbl allosteric inhibitor, has demonstrated safety and efficacy in mice with neuronal damage, Alzheimer's, and Niemann-Pick Type A disease. We suggest that Neurotinib may provide a therapeutic option for vascular calcification. This study aimed to determine if inhibition of cAbl arrests the progression of vascular calcification in vivo and in vitro. A high-fat, atherogenic diet induced atherosclerosis and vascular calcification in apolipoprotein-e deficient (Apoe-/-) mice for 25 weeks. Mice were placed into four groups based on when they received treatment: no Neurotinib, Neurotinib (67ppm) after 20 weeks, after 15 weeks, and for all 25 weeks. Neurotinib significantly reduced the progression of vascular calcification in all mice. Vascular smooth muscle cells were cultured in pro-calcific (osteogenic) conditions with Neurotinib. After 21 days, the cells with Neurotinib had significantly decreased vascular calcification. This study demonstrates the potential for Neurotinib to prevent vascular calcification formation in vivo and in vitro.



PTS-based approach for Augmented Data Gloves for jaBCI

Author: Peeyush Awasthi

Faculty Advisor: Dr. Raj Pulugurtha

In our earlier work on joint angle Brain-Computer Interfaces (jaBCI), we employed the Cyber Glove 3 systems (Figure 1, highlighted sensors in yellow) to capture finger kinematics via 19 sensors. Despite delivering highly accurate joint angle readings—precise to within one degree (approximately 0.01753 radians)—these devices did not account for the unique anatomical features of each user's fingers. To fully harness the hand's extensive degrees of freedom (27 in total, controlled by 34 muscles), we investigated various hand postures (Figure 1) to enrich jaBCI control. Subsequently, we introduced micro-sized patch antennas resonating at 94 GHz as wearable sensors on finger joints (Figure 2), capitalizing on the suitability of patch antennas for this application. Building on that foundation, we have now explored a new approach using process test structures (PTS). These structures detect micrometer-level shifts or misalignments—whether lateral, vertical, or circular—by printing annular rings (9 and 10 µm) directly onto a glove. As the finger knuckles bend, the rings shift, thereby producing measurable variations. Here, the focus is not on mapping precise bending angles but rather on quantifying the tiny (on the order of 10–20 µm) positional offsets resulting from a small finger bend of just a few degrees. We modeled this curvature-induced displacement in SolidWorks and simulated it with Ansys HFSS (Figure 2, right). Observed frequency deviations at the resonant peak (Figure 3) serve as indirect measurements of these misalignments, arising from the antenna's changing electrical properties under curvature.

This augmented Data Glove therefore offers highly personalized signal outputs. Beyond enhancing Brain-Computer Interface studies, it opens new opportunities in augmented reality and the real-time control of complex tasks across varied domains.

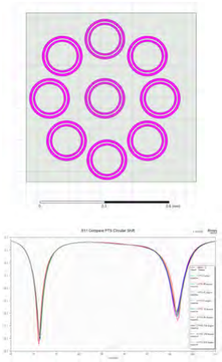


Fig. 3: Different resonating frequencies for PTS position/ misalignment positions like center, 900, 450, 00, -450, -900, -1350, -1800, -2250, all PTS (together)

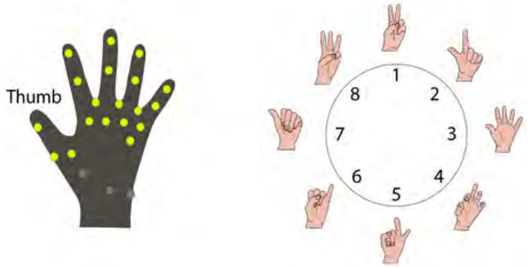


Fig. 1: (Yellow) Sensors on Data Glove with Postures used in jaBCI (joint angle Brain Computer Interface) model

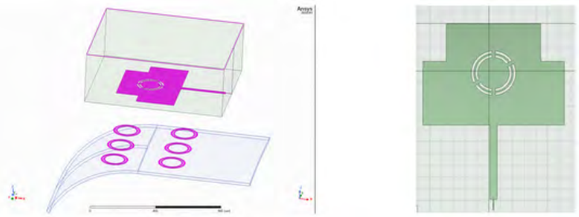


Fig. 2: Patch Antenna Sensor (Right) and PTS printed on glove (Left) shift due to bend motion of finger joint angles

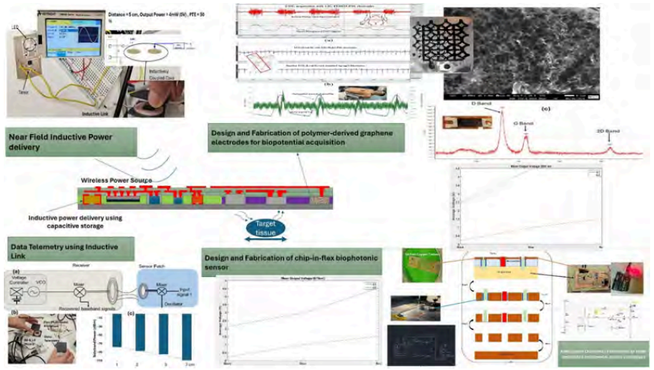
Multimodal Wearable Health-Monitoring Patches with Co-Packaged Sensing, Data Telemetry and Power Delivery

Authors: Reshmi Banerjee, Ramfel Santos, Ghaleb Al-Duhni, Veeru Jaiswal, Nobel Amadi and Raj Pulugurtha

Faculty Advisor: Dr. Raj Pulugurtha

This work aims to advance three key innovations including size, power, and reliability in epidermal health-monitoring with embedded devices in flexible fan-out packages that can withstand considerable bending or stretching without any resulting damage or loss of electrical and/or structural integrity. The flex embedded system components with screen printed silver polyurethane traces, form a low form factor (< 2g, < 2 cm) sensor, with Near Field Inductive coupling supporting both power (50 % PTE) and data telemetry for untethered continuous monitoring at 40 kHz or 10 MHz. Efficiency of data telemetry is estimated by characterizing the path loss (dB) as the difference between the transmitted and received power (dBm) at the specific resonant frequency and higher losses are attributed to mismatch between the coil and receiving components.

Late identification of critical behavioural risk factors for heart disease and stroke underscores the need for cost-effective, non-invasive, long-term cardiac monitoring alternatives and analysis of electrophysiological signals to improve cardiovascular disease diagnosis, treatment options for altered disease outcome longer survival times. The primary goal of this work is to design and develop energy-efficient autonomous sensing platforms to facilitate uninterrupted, long-term remote monitoring of multiple electrophysiological parameters including tissue oxygenation, electrocardiogram (myocardial conduction), seismocardiogram (local vibrations of chest wall), and electromyogram (neuromuscular conduction of skeletal muscles). Commercial Ag/AgCl wet electrodes that use a conductive gel for signal transduction, are often subject to dehydration, high skin-electrode contact impedance and skin irritation for longer periods of monitoring. Appropriate biocompatible dry electrode material (Laser Induced Graphene and PEDOT:PSS composite) with matching human skin modulus (GPa), conformal device–tissue contact, low electrode–skin interface impedance (~ 200 Ω), and form-factor allows high quality signal acquisition and minimize potential delamination at the skin-surface electrode interfaces. The comparison functional validation study of LIG-PEDOT:PSS sensors against standard Ag/AgCl electrodes have shown high-fidelity in acquired ECG and EMG time domain signals (Fig.1). The novel passive seismocardiogram sensor incorporates piezoelectric properties of polyvinyl difluoride (PVDF) thin-films for mechanical motion detection along-with stretchability, conductivity and mechanical strength of porous LIG-PEDOT:PSS composite for high SNR signal acquisition and is found to be more sensitive as compared to standalone PVDF sensors. Based on the principle of continuous-wave multi-distance optode configuration, two embedded NIR light emitter sources (670 nm, 850 nm) and a photo-detector is used to estimate the oxygen saturation by chromophores, as the backscattered light intensity at optode separation distances of 5mm (C1) and 50 mm (C2) using colored and black pigments with scattering agents passed through an Agar phantom. At 675 nm, the mean output voltage shows a linear trend and colored pigments display higher reflectance than the black pigment for both channels, whereas at 850 nm, the linear trend is observed for C2, while reflectance of blue and red pigments is approximately unchanged for C1 (Fig.1). The Single Layer Integration with Component Embedding (SLICE) packaging approach allows low-loss interconnects, smallest footprint and optimized partitioning of the functions for system performance.In vitro phantom validation and benchmarking against current sensors have demonstrated EMG, ECG, SCG and NIRS functionality under field conditions. Future work would focus on extending the sensors to other functions such as mechanomyogram and biophotonics. The multimodal sensing device would also be characterized in terms of Accuracy and Sensitivity and benchmarked against commercially available multimodal sensing platforms. Reliability of multimodal sensing systems are strongly dependent on data analysis. Thus, the integration of Deep Learning (CNN-LSTM and/or Bi-LSTM) algorithms for automatic data classification and anomaly detection would ultimately assist automatic cardiac event screening and risk-assessment.

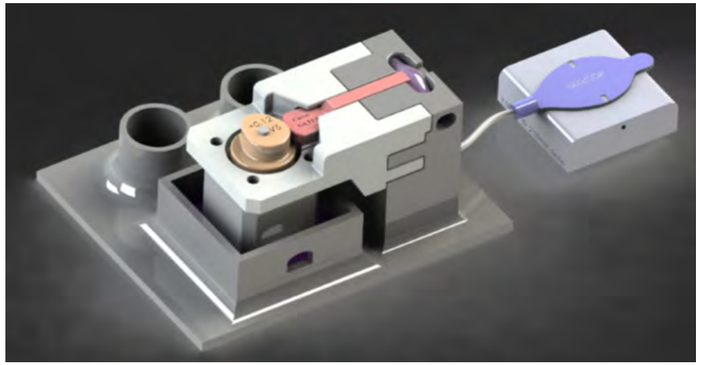


Development of Evaluation Platform Optical Wearable System for Underserved Population

Authors: Mel Tananant Boonya-ananta, Andres Rodriguez, Ajmal, JunZhu Pei, Amanda Sanchez, Ernesto Rodriguez and Jessica Ramella-Roman

Faculty Advisor: Dr. Jessica Ramella-Roman

Cardiovascular disease remains one of the leading causes of death in the United States. Currently, over 40% of the population lives with some form of cardiovascular condition as well as varying degrees of obesity, a significant risk factor for CVD. With the ever-expanding market for health wearable systems, research has exposed some significant shortcomings in accurately capturing health conditions. Many of these systems utilize optical techniques such as photoplethysmography (PPG) to probe for changes in the cardiac output waveform through the skin and surrounding tissues. This signal is impacted by varying skin tones and physiological changes to obesity in our diverse population. To aid in the development of these optical monitoring technologies, we have developed a dynamic phantom testing platform incorporating optical and mechanical properties of the tissue surrounding the radial artery at the wrist. The phantoms consist of three main features: a silicone body with optical properties representative of surrounding skin layers ranging from Fitzpatrick skin type I-VI at 660 nm, a vessel chamber with mechanical properties representative of the radial artery, and a pulsatile pump that cycles a blood-mimicking fluid to maintain physiologically accurate pressure fluctuations typically seen at the radial artery. This phantom is developed through the combination of rapid prototyping using both stereolithography (SLA) and fused deposition modeling (FDM) methods to develop mold casting with a silicone-based material to control geometric properties. PPG signal for different properties representing varying skin tone and obesity is collected using a commercial NellCor Pulse Oximeter device.

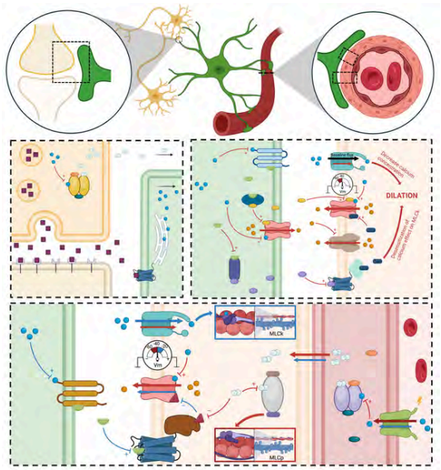


Unraveling the nonlinear nature of the neurovascular coupling

Authors: Alejandro Suarez, Lazaro Fernandez, Nina Perrotti and Jorge Riera

Faculty Advisor: Dr. Jorge Riera

A deeper understanding of the neurovascular coupling (NVC) is vital to improve the clinical power of functional imaging techniques, elucidate the pathogenesis of several neurodegenerative diseases, and understand brain functioning in general. Astrocytes have been proposed to mediate this communication between neurons and the vascular supply in the last two decades. However, their contribution to the NVC remains very contested due to the nonlinear nature of this phenomenon. Previous experimental studies have produced contradictory results about this contribution mainly due to the inability to isolate the astrocytic-mediated biochemical pathways during neuronal stimulation. Thanks to a double transgenic mouse line that our lab imported from Riken Lab in Japan, we are able to optogenetically stimulate calcium signals in cortical astrocytes and measure the induced changes in localized cerebral blood flow (CBF) using laser Doppler flowmetry (LDF). By contrasting the CBF response to isolated astrocytic stimulation and sensory stimulation combined with pharmacological manipulation to block the different biochemical pathways, we can characterize their contribution. Our results suggest that the involvement of astrocytic-mediated pathways is more related to long-sustained stimulation, and maintenance of the vascular tone, whereas neuronal pathways are more involved in short-transient stimulation. We demonstrated the presence of an astrocytic-calcium-dependent mechanism of vasoconstriction via secreted phospholipase A2 (sPLA2) that competes with the vasodilatory one via nitric oxide (NO) signaling coming from endothelial cells in response to shear stress. We believe that crosstalk between these two mechanisms establishes an equilibrium in baseline vessel diameter that allows for the effective relocation of blood supply in response to localized demands.

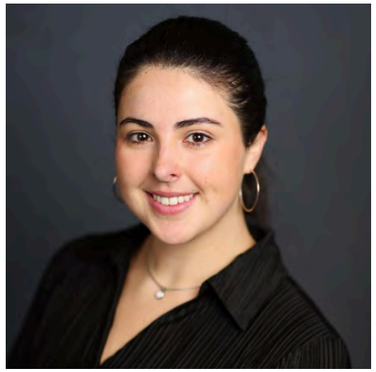


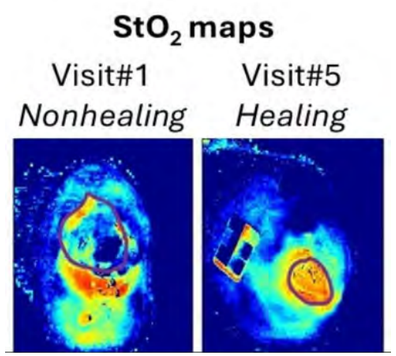
Objective Assessment of the Healing Status of Diabetic Foot Ulcers of Various Skin Colors Using a Smartphone-Based NIRS Device

Authors: Daniela Leizaola and Anuradha Godavarty

Faculty Advisor: Dr. Anuradha Godavarty

A smartphone-based near-infrared spectroscopy (NIRS) device (SPOT-smartphone-based oxygenation tool) was developed for remote patient monitoring of diabetic foot ulcers (DFUs). To date, SPOT has been validated through phantom studies and in-vivo studies against a commercial device. Melanin is present in the periwound region but absent in the wound bed; thus, its effects were accounted for, to produce true tissue oxygenation measurements in near-infrared imaging. A melanin correction factor (MCF) was developed using Monte Carlo simulations to account for melanin, as well as variations in skin color among the population (based on the Fitzpatrick skin type scale). The current study focuses on applying this MCF to develop an objective assessment of healing status of diabetic foot ulcers using SPOT. Seven DFU subjects were recruited and imaged using the SPOT device for up to 8 clinical visits. Data analysis involved a correction of imaged diffuse reflectance using a melanin correction factor (MCF) followed by the extraction of oxygen saturation (StO_2) via a modified Beer-Lambert law. StO_2 maps were generated and analyzed to assess the impact of MCF on tissue oxygenation values and to compare differences between healing and non-healing diabetic foot ulcers. Results demonstrated that the MCF affects the StO_2 map more as FST increases but does not change the qualitative spatial trend of the map. Specifically, healing wounds exhibited an increase in StO_2 within the wound area relative to the surrounding tissue as healing progressed, while non-healing wounds showed no distinct variation in StO_2. Ongoing work involves further subject recruitment and statistical model comparisons to achieve optimal sensitivity/specificity relationship for objectively evaluating DFUs.





Battery-less, Lightweight, Wireless Sensor for Biopotential Recording in Swine

Authors: Melany Gutierrez-Hernandez, John Volakis and Jorge Riera

Faculty Advisors: Dr. John Volakis and Dr. Jorge Riera

Wireless recordings are vital for continuous mapping of the seizures' focus on epilepsy patients. For the first time, we validated our novel packaged battery-free and wireless neurosensing system (WiNS) in large animals (swine) with induced epilepsy. Previous recorders remained prohibitively large due to their antenna size and associated impedance matching circuits. Our proposed implant was miniaturized by ~50% employing a multilayer 3D printed design. Although pigs are increasingly being used to study human neurodegenerative diseases, a chronic epilepsy model for pigs is not yet available in the literature. In this study, we propose a model to induce epilepsy in swine using kainic acid, similar to the process described in [1]. We have also designed the implant connected to an ECoG array for fully implantation at the cortex, targeting the brain region that detects somatosensation (S1, see Fig. 1). This package was implanted in sedated pigs using a sterile surgical procedure stated in the protocol (No. 23–023) and approved by the Institutional Animal Care and Use Committee (IACUC) at Florida International University. After recovering, the animal was completely mobile and free of protruding wires with our implanted passive recorder. Spontaneous neural activity was recorded with our proposed implant while the pigs freely moved in their cage. Our presented recordings and results demonstrate functional validation of our novel packaged, miniaturized recorder while performing in-vivo measurements (see Fig. 2).

Fig. 1 A) Surgical placement of implant, ground screw and ECoG array in open craniotomy above S1. B) Microsyringe injection of 20 µg of kainic acid into S1. C) Still photo from video taken while recording with the WiNS when pig is awake and standing.

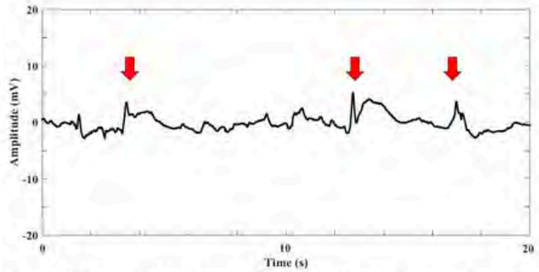


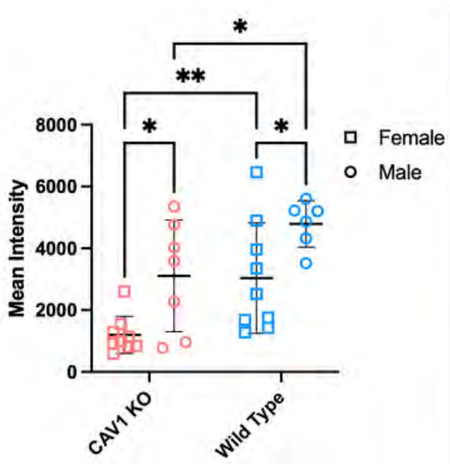
Fig. 2 Recordings from the WiNS implant while the pig was awake and standing (see Fig. 1C). Red arrows indicate putative sharp waves.

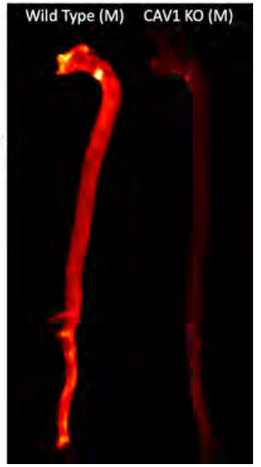
Investigating the dependency of caveolin-1 in vascular and valvular calcification

Authors: Sophie Ashbrook, Valentina Dargam and Joshua Hutcheson

Faculty Advisor: Dr. Joshua Hutcheson

Vascular and valvular calcification represents the most significant predictor of cardiovascular events with no current therapeutic options for prevention or treatment. Osteogenically-differentiated vascular smooth muscle cells (VSMCs) and valvular interstitial cells (VICs) release calcifying extracellular vesicles (EVs), which nucleate nascent mineral. Caveolin-1 (CAV1), a plasma membrane scaffolding protein residing in caveolar domains, plays a critical role in the formation of calcifying VSMCs EVs. However, the role of CAV1 in formation of calcifying EVs from VICs remains unknown. We hypothesized that CAV1 plays an important role in calcification within the valve similar to its function in the vasculature. To test this hypothesis, CAV1 knockout (KO) mice (N = 16) and C57BL/6J wild type mice (N = 15) were placed on a chronic kidney disease diet model to induce valvular and medial calcification. Upon endpoint, aortas and aortic valves were collected from the mice and calcification was quantified using calcium tracer Osteosense 680 and a custom MATLab code. Calcification in the aorta of the CAV1 KO mice exhibited significantly less calcification ($p < 0.01$) than the wild type mice. However, within the valve, CAV1 mice exhibited significantly higher levels of calcification ($p < 0.05$) than the wild type mice. In vitro, both VICs and VSMCs cultured under the same osteogenic conditions, both exhibit robust calcification. Our results suggest that CAV1 is required for EV biogenesis within the vasculature but not for the valve. Future studies will further investigate the role of CAV1 in the valve and the biogenesis of VICs calcifying EVs.





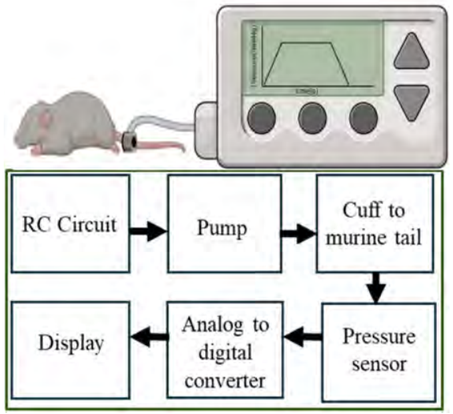
POSTER PRESENTATIONS

Development of a small animal pressure occluding device for mapping peripheral hemodynamic flow patterns in the murine tail

Authors: Aasma Dahal, Shirel Belilty, Alejandro Mijares, Astrid Padilla Castillo, Harold Hoerning, Mohammad Amroush, Adam Felch, Daniela Leizaola, Joshua Hutcheson and Anuradha Godavarty

Faculty Advisor: Dr. Anuradha Godavarty

Vascular calcification (VC) is a leading contributor to cardiovascular diseases. Despite the availability of different modalities for vascular calcification detection, these imaging techniques are often expensive and not easily accessible. To address this issue, our lab developed a low-cost NIRS-based imaging technique (NIROS- near-infrared optical scanner) to detect VC by measuring the hemodynamic flow differences in the murine tail. In our previous studies, a commercial occlusion cuff (CODA monitor) was used to occlude the murine tail and NIROS captured the hemodynamic changes in mice in response to total occlusion (250mmHg). However, this device lacked the ability to control the pressure and the occlusion paradigm. Herein, we custom-developed a small animal pressure occluding device capable of precise pressure control to allow venous, arterial, and total occlusion (including hypoxic conditions). The custom-pressure occlusion device is capable of changing the rate of occlusion, the maximum pressure and time of occlusion, the rate of relaxation, and time period between repeatable occlusion cycles. This allows inducing venous, arterial as well as total occlusions in a controlled manner. Our ongoing work is focused on determining the peripheral hemodynamic changes in response to various occlusion paradigms and determine the least pressure and distressing protocol that can help detect VC, via studies on control mice.

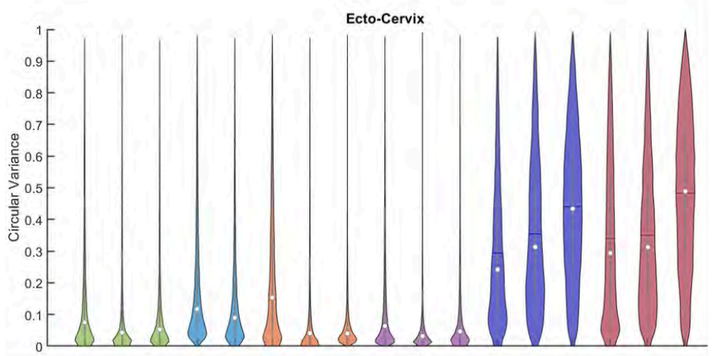


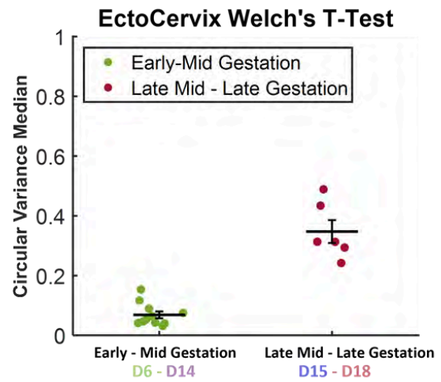
Depth-resolved Mueller Matrix analysis of cervical remodeling in pregnant mice

Authors: Ajmal Ajmal, JunZhu Pei, Mala Mahendroo, Tatiana Novikova, and Jessica Ramella-Roman

Faculty Advisor: Dr. Jessica Ramella-Roman

Preterm birth remains a significant challenge in maternal and neonatal healthcare. During pregnancy, the uterine cervix undergoes extensive remodeling to facilitate successful childbirth. The extracellular matrix (ECM) plays a crucial role in this remodeling process, influencing cervical biomechanics and its ability to maintain structural integrity throughout gestation. However, the early softening of the uterine cervix, resulting from accelerated remodeling of the cervical ECM, can lead to preterm birth. In this study, we employed Mueller matrix polarization imaging of the cervical tissue in mice at various stages of pregnancy. We analyzed the polarization parameters to assess the associated cervical collagen remodeling. The imaging was conducted using our custom polarimeter, which provides transmission and reflection light Mueller matrix microscopy images, referred to as TRIMMM. Our research focuses on the depth-resolved assessment of the ECM structure evolution in mouse cervix sections, spanning from the external to the internal OS, at different gestational stages. The polarization parameters derived from the Mueller matrix effectively map the tissue microstructure and composition of the cervical ECM, thanks to the optical anisotropy of the collagen fibers present. Our statistical analysis of the Mueller matrix results provides valuable insights into the variations in microstructural organization of the cervical ECM at depths on days 6 to 18 of gestation in mice. These findings highlight the potential of polarization-sensitive imaging techniques for the accurate and rapid diagnosis of preterm birth risk in clinical settings, contributing to the development of risk prediction and targeted interventions.



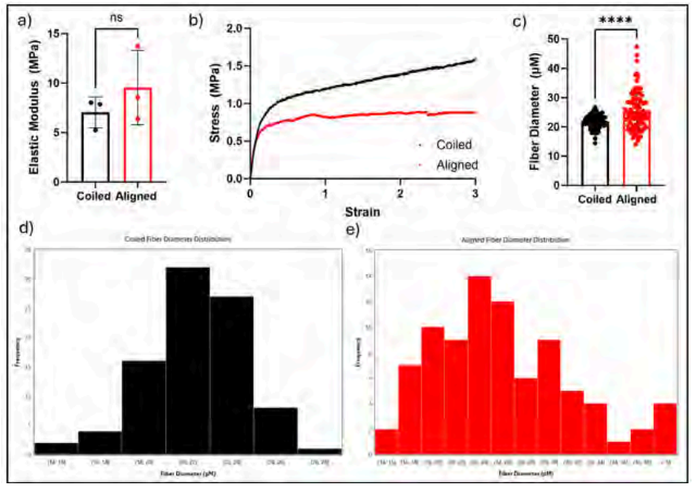


In-Vitro Response to Bioinspired Helically Coiled Electrospun Fibers for Cardiac Patch Application

Authors: Alexi Switz, Darryl Dickerson and Anamika Prasad

Faculty Advisor: Dr. Anamika Prasad

The electrospinning method is increasing in tissue engineering due to its ability to produce fibers in the nanometer to micrometer range. Such applications also demand greater control on fiber formation since fiber orientation dictates mechanical flexibility, strength, porosity, and cellular response. Here we present the characterization of helically coiled and aligned electrospun fibers including analysis of elastic moduli via tensile testing, fiber diameter and pore size via imaging and cellular response. Helically coiled structures were chosen for fiber design since such structures are common in nature in both the plant and animal worlds but have found limited application in tissue engineering. Polycaprolactone, an FDA-approved material was used for fiber formation. The function and biocompatibility of fibrous scaffolds was tested including its response to cardiomyocytes and fibroblasts using a specially designed tissue setup. The outcome was compared with aligned fibrous mats to evaluate the effectiveness of helical coiling.



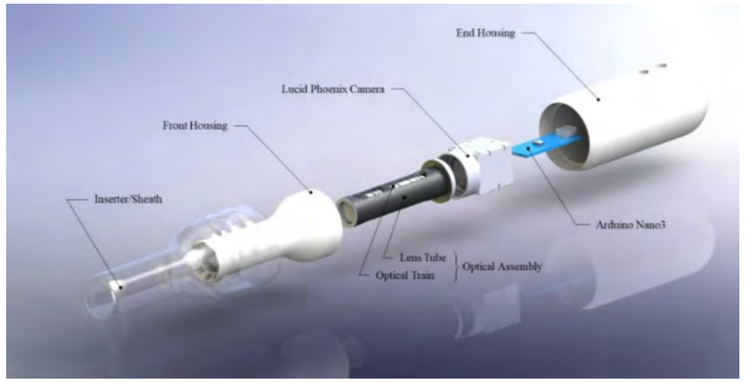
Development of a Portable Preterm Imaging System (PPRIM)

Authors: Amanda Sanchez, Tananant Boonya-Ananta, Jun Zhu Pei, Ajmal Ajmal, Gianella Escusel and Jessica Ramella-Roman

Faculty Advisor: Dr. Jessica Ramella-Roman

Preterm birth remains a significant global health challenge, with approximately 13.4 million cases recorded in 2020. Infants born before completing 37 weeks of gestation face heightened risks of severe health complications and long-term disabilities. While treatments exist for women with a history of preterm birth complications, there is currently no diagnostic test that can reliably predict preterm birth risk. Spontaneous preterm birth can result from a variety of biological and environmental factors, which contribute to premature mechanical changes in the cervical structure as the uterus prepares for delivery. These structural transformations, collectively referred to as cervical remodeling, occur in three distinct phases: softening, ripening/dilation, and postpartum repair. Softening is significant, as it involves modifications in collagen orientation and mechanical properties. Fibrillar collagen, a key structural protein, plays a critical role in determining the cervix's load-bearing capacity, with its assembly directly influencing mechanical strength. Located within the extracellular matrix (ECM), collagen provides structural integrity and mechanical support to cervical tissue. Studies have shown that abnormalities in the extracellular matrix (ECM) organization of the cervix often precede spontaneous preterm birth. To address this, the Portable Preterm Imaging System (PPRIM) has been developed to capture data on cervical collagen, which can be used to determine preterm birth risk.

The PPRIM is a sophisticated optical imaging system that functions as a portable microscope, enabling high-resolution cervical imaging. Its optical system consists of micro-LEDs emitting light at a 511 nm wavelength, covered with polarization sheets to produce polarized illumination. A carefully designed optical train, incorporating a reverse telephoto lens and a telecentric relay, directs the reflected light from the cervix onto a polarized camera sensor housed at the front end of the device. To validate the feasibility of the device, a series of imaging and calibration tests were conducted on various components of the optical system. Additionally, efforts have been made to establish a connection between the mechanical properties of cervical tissue—such as stress and strain—and polarization-related parameters derived from Mueller Matrix decomposition, including linear retardance.

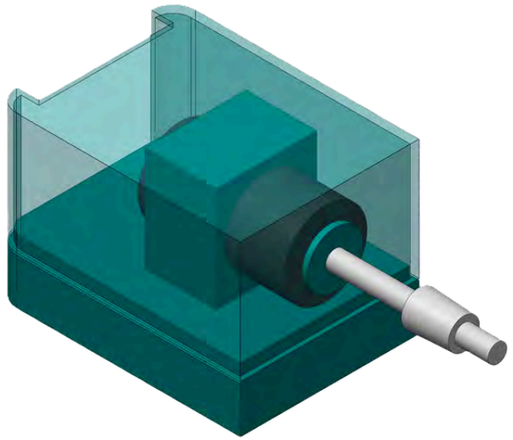


A 3D-Printed Electrospinning Collector for Fibrous Valvular Scaffolds

Authors: Ariadna Herrera, Jennifer Acevedo Padron, Anja Mihajlov and Anamika Prasad

Faculty Advisor: Dr. Anamika Prasad

Congenital heart defects are one of the most common birth defects in the United States. These defects can impact different parts of the heart, such as the atria, ventricles, and valves. While adults that have valve disease can receive a valve replacement using mechanical or bioprosthetic valves, infants born with congenital valve defects have limited treatment options. This is primarily due to the inability of mechanical and bioprosthetic valves to support somatic growth, leading to a life of multiple reoperations and decreased quality of life. Research groups have investigated tissue engineering valves using different scaffold materials, such as hydrogels, decellularized biological tissues, natural polymers, and synthetic polymers. Our initial material focus was decellularized porcine tissue, but we ultimately found that this scaffold material fails under physiologically relevant flow conditions. We have turned our current efforts towards creating a fibrous, electrospun polycaprolactone (PCL) scaffold that can be utilized for valvular applications. PCL is a popular biodegradable polymer in the field of tissue engineering. Electrospinning allows us to form fibrous scaffolds of different fiber orientations, properties, and geometries through the experimental set up and collector geometry. We have 3D-printed a collector that is comprised of a motor housing and a tubular collector. The tubular collector is segmented to allow the formation of 20mm long cylinders that have an increasing diameter of 14mm to 16mm. This part is connected to a motor that will cause it to spin while PCL is ejected to form fibrous cylindrical scaffolds.



Hippocampal Sharp Wave Ripples in Freely Moving Marmosets: Features, Phase-Amplitude Coupling, and Associations with Body and Head Movements during Navigation

Authors: C. Otero, D. B. Piza, J. C. Martinez-Trujillo, J. Riera

Faculty Advisor: Dr. Jorge Riera

Sharp wave ripples (SWRs) are neurophysiological events observed in the hippocampus, characterized by a combination of a low-frequency sharp wave (SW) and high-frequency oscillations (ripple). These events result from synchronized neural firing within the Cornu Ammonis (CA) of the hippocampus and have been linked to memory transfer and consolidation from hippocampus to other cortical areas of the brain. Although SWR are thought to be universal across species, most studies have been conducted using a rodent model or head-restrained macaques. Studies utilizing freely moving primate models are scarce; however, could enhance the translational value to understand memory in a more naturistic setting. This study focused on detecting SWRs within a freely moving marmoset model (n=2 animals) who underwent two distinct navigation tasks:1) Foraging, and 2) Sequencing (Figure1). We analyzed SWR characteristics, including spectral properties, phase-amplitude coupling (PAC), and behavioral correlations. Distribution fitting of SWR features revealed consistent trends across sessions, while PAC analyses identified ripple amplitude preferences at specific SW phases, typically around 0° and 180°. Additionally, the SWRs detected typically occurred at states where both head and body were stationary (68.4% of events detected) as well as an increase of SWR rates when the head view or body location was at a reward site compared to other maze locations (mean reward .027 vs other .011 SWRs/s for head view and mean rate reward .057 vs other .021 for body location). This study provides insight into the relation of these memory engram signals with the navigation patterns of freely moving marmoset, as well as the general trend of these events. By linking hippocampal activity to naturalistic behavior, this study provides valuable insight into how SWRs support memory-guided navigation in primates. Understanding these dynamics in freely moving models may help uncover mechanisms underlying disordered spatial processing in neurological conditions, offering a foundation for future translational research into cognitive and memory-related impairments.

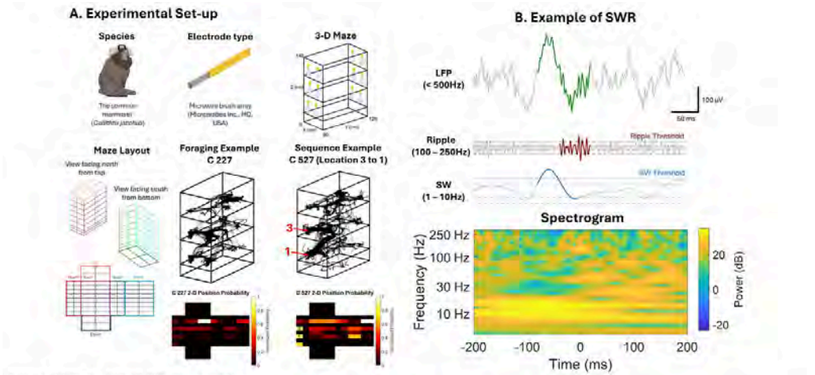


Figure 1. Experimental Set-Up and Example of a SWR
A. Marmosets (n=2) were implanted with a chronic microwire brush array in either CA1/3 of HPC and placed in a 3Dmaze. There were two types of Navigation tasks used in this experiment: 1) Foraging and 2) Sequence, where in foraging the animal is randomly rewarded food at sites that randomly cued (12 possible sites) while in sequence the animal must remember a specific sequence of two sites to receive reward (Site 1 and 3 in this example). **B.** Here is an example of a SWR LFP frequency range (green), the ripple range (red) and the SW range (blue) (dashed lines represent upper and lower thresholds for detection, frequency bands listed to the left). Underneath is a scalogram depicting the interplay of the spectral components during a 400ms time window centered at the ripple peak of this specific example.

Exploring Macrophage Role in Valve Health: From ECM Remodeling to Calcification

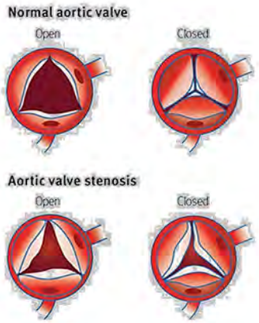
Authors: Claudia Ponce-Aportela and Joshua Hutcheson

Faculty Advisor: Dr. Joshua Hutcheson

Introduction: Heart valves rely on a highly organized extracellular matrix (ECM) composed primarily of fibrillar collagen, elastin, and glycosaminoglycans to maintain unidirectional blood flow. Resident macrophages comprise up to 75% of valvular immune cells. The presence of macrophages in tissue remodeling, immunomodulation, and calcification suggest that they play a major role in pathologies such as aortic valve stenosis. Previous studies have demonstrated that macrophages can alter cytokine profiles and disrupt ECM turnover, resulting in compromised valvular function. In most situations, leukocyte-derived macrophages only enter tissues following insult, wherein they participate in remodeling, and if unchecked, disease progression. However, the role of resident macrophages in normal heart valve homeostasis remains unclear. This investigation aims to elucidate the interplay between heart valve resident macrophages in both normal ECM maintenance and remodeling.

Methods: We will use two complementary in vivo murine models. In the first, healthy adult mice will receive clodronate liposomes to deplete macrophages, enabling the assessment of ECM stiffness, calcification, and ECM organization using advanced imaging techniques and immunofluorescence. In the second, a specialized diet will induce heart valve calcification in order to examine macrophage involvement in pathophysiological conditions. Markers such as matrix metalloproteinases (MMPs) will be assessed to characterize ECM remodeling processes and gauge macrophage-dependent proteolysis.

Discussion: These models will clarify whether macrophages support or exacerbate calcification by orchestrating tissue repair and inflammation. Correlating macrophage depletion with alterations in ECM composition and valvular mechanics will reveal novel insights into the cellular and molecular drivers of valve disease. Ultimately, elucidating the contribution of macrophages to normal and diseased valve ECM may inform future therapeutic approaches aimed at modulating their activity to preserve or restore valvular function.

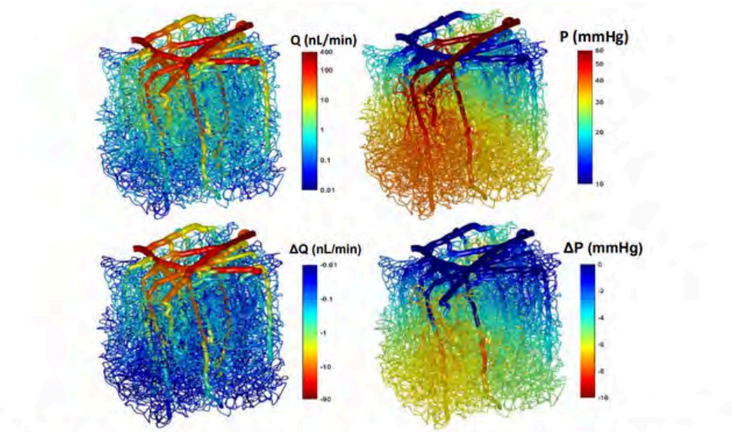


A Multiscale Modeling Framework for Predicting Blood Flow Regulation in the Brain

Author: Dabasish Kumar Saha

Faculty Advisor: Dr. Nikolaos Tsoukias

The regulation of cerebral blood flow (CBF) relies on intricate mechanisms that span from subcellular signaling pathways to the modulation of vessel tone and overall hemodynamics. Proper CBF regulation is vital for normal brain function, while its disruption is linked to neurological conditions such as Alzheimer's disease, dementia, and small vessel disease. However, the precise processes that maintain consistent blood perfusion in the brain are not yet fully understood. Due to the complexity of the brain's vascular architecture and the difficulty of direct experimental observation, computational modeling serves as a powerful tool to investigate CBF regulation. This study presents a multiscale modeling framework that simulates CBF dynamics within anatomically accurate microvascular networks. The model integrates detailed cellular representations to build multicellular vessels within reconstructed vascular structures. By incorporating biomechanical principles, the framework translates electrical and calcium signals into vessel diameter changes, enabling predictions of hemodynamic behavior at the tissue level. The model accounts for active regulation by allowing vessel diameters to adapt in response to pressure, flow, and external stimuli. Simulations show that myogenic constriction along arteries and capillaries, driven by intravascular pressure, impacts blood perfusion distribution. The results indicate that both arteriolar smooth muscle cells and capillary pericytes help maintain consistent flow under varying inlet pressures, while pial arteries have minimal influence on restricting blood supply. These findings highlight capillaries and small penetrating arterioles as key regulators of network resistance and myogenic autoregulation, offering a theoretical framework to study CBF regulation in both healthy and diseased states.



Predicted blood flow and pressure distribution in a "static" cerebral microvascular network. Changes in blood flow and Pressure due to myogenic constriction in arteries.

Tissue curvature correction of irregular surfaces in NIRS imaging based on Monte-Carlo simulation

Authors: Himaddri Shakhar Roy, Charles Policard, Kacie Kaile and Anuradha Godavarty

Faculty Advisor: Dr. Anuradha Godavarty

NIRS imaging modalities can measure the tissue oxygenation of diabetic foot ulcers (DFUs) to assess the healing status. However, wound surfaces in real-life scenarios are curved, particularly in amputated feet. Due to the inability of a detector to capture signals from various planes of curved surfaces, the diagnosis may provide an inaccurate measurement of tissue oxygenation. The changes in spatial optical measurements may result from variations in the underlying physiology or from the curvature of the tissue surface. Hence, the effect of tissue curvature must be removed to get accurate tissue oxygenation measurements. The objective of the study is to develop and implement a mathematical model to correct the diffuse reflectance signal for tissue curvature effects via simulated phantom studies using Monte-Carlo light propagation models. A simulation study was conducted on convex and concave wound models for different radius of curvature (1.5 cm to 3.5 cm) using uniform and gaussian light distributions. The height and angle correction factors were applied to the diffuse reflectance signal to correct the detected signal according to the 3D distribution of the geometries. The preliminary results showed that concave geometries do not need correction, and convex geometries need both height and angle correction. The percentage median error before correction for the convex geometries ranges from 9.4% to 9.67%, and the correction reduced the error down to the range of 0.03% to 2% across different radius of curvatures. Currently, extensive studies on irregular geometries and analyzing the effect of this correction factor on hemoglobin concentration maps are ongoing.

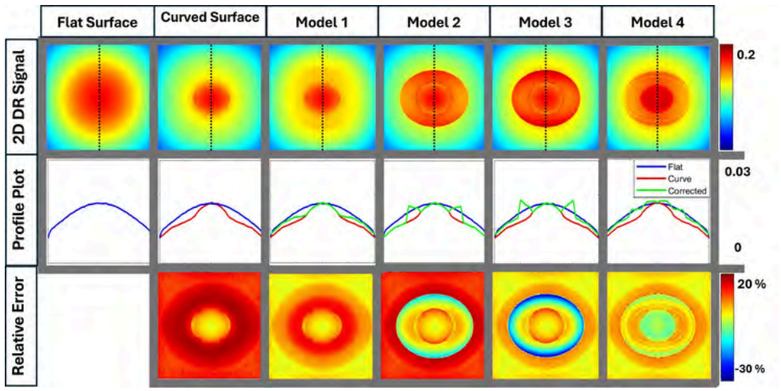


Figure: 2D DR maps, profile plots of DR signals along y-axis at x=0 cm (shown by a dotted line in the 2D DR maps), and the relative error with and without the various correction models applied. The above maps are based on DR signals obtained at 690 nm and using a Gaussian light source

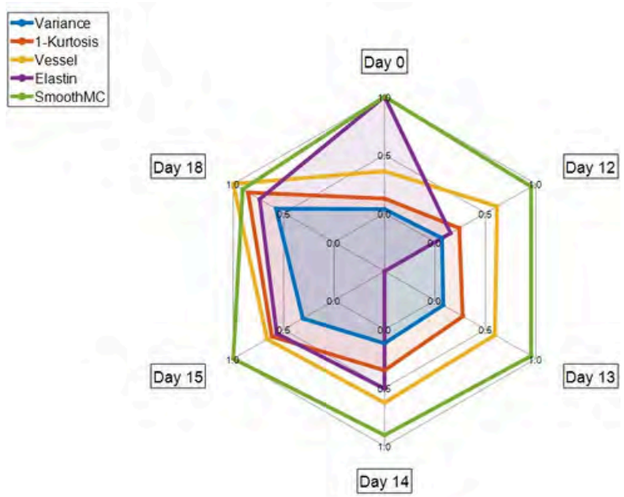
Multimodal Imaging of Cervical Remodeling in Pregnancy

Authors: JunZhu Pei, Ajmal, Amanda Sanchez, Tananant Boonya-Ananta, Daniela Giammattei, Andres Rodriguez and Jessica Ramella-Roman

Faculty Advisor: Dr. Jessica Ramella-Roman

Preterm birth (PTB) is a leading cause of neonatal morbidity and mortality, often associated with abnormal cervical remodeling. This complex process involves biochemical and structural changes that prepare the cervix for labor, including alterations in collagen and elastin organization, smooth muscle cell density, and vascular adaptations. Disruptions in these changes can contribute to spontaneous preterm birth (sPTB), underscoring the need for improved diagnostic tools to assess cervical remodeling.

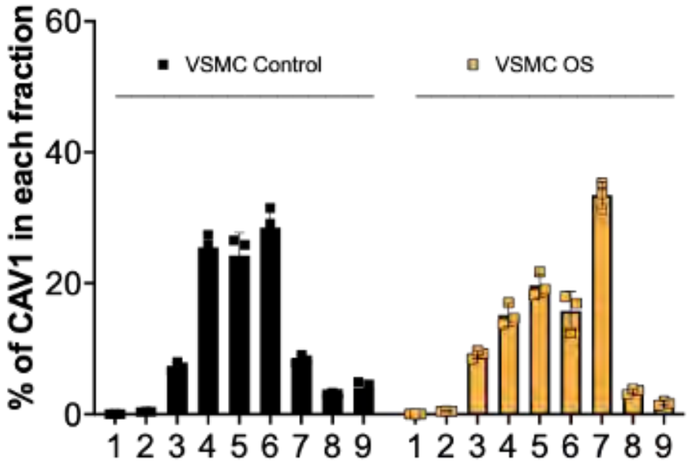
This study utilizes a multimodal imaging approach to investigate cervical remodeling in pregnant mice at different gestational stages. Mueller Matrix Imaging was employed as a primary optical modality to assess alterations in tissue birefringence, depolarization, and diattenuation, offering quantitative insights into collagen and elastin organization. To validate and expand upon these findings, complementary histological techniques—including Hematoxylin and Eosin staining, tartrazine clearing, and fluorescent and brightfield imaging—were used to examine extracellular matrix composition, smooth muscle distribution, and vascular remodeling. This integrated analysis provided a detailed characterization of cervical softening, ripening, and dilation, correlating imaging parameters with key structural and cellular transformations. By combining advanced optical imaging with traditional histological methods, our study enhances the understanding of cervical remodeling and its role in PTB risk. These findings contribute to the development of improved diagnostic strategies, potentially enabling early detection of abnormal cervical changes and informing targeted interventions to improve maternal and neonatal health outcomes.



Characterization of Relevant Lipid Profiles in the Mechanism of Vascular Calcification

Authors: Katherine Kaiser, Marissa Carter, Amirala Bakshian Nik, Francisco Lima and Joshua Hutcheson
Faculty Advisor: Dr. Joshua Hutcheson

Vascular calcification is the most significant predictor of an individual's risk for a cardiovascular event. In response to pathological conditions, such as chronic kidney disease, hypertension, and atherosclerosis, vascular smooth muscle cells (VSMCs) undergo an osteoblast like phenotypic shift and produce calcific mineral to stabilize the arterial microenvironment. While this process mimics the mineralization mechanism of osteoblasts, many cellular mechanisms underlying vascular calcification remain unknown. We have previously shown that VSMCs depend on the trafficking protein caveolin-1 (CAV1) to produce calcification. Additionally, density gradient separation experiments suggest that CAV1 relocates from cholesterol-rich caveolar domains to heavier, non-caveolar density fractions during VSMC-mediated calcification. To further investigate the trafficking of CAV1 and its role in vascular calcification, we have conducted an unbiased lipidomic characterization analysis to identify the lipid profile co-localizing with CAV1 in this process. We aim to elucidate which lipid classes participate in the mechanism of vascular calcification, thereby advancing our fundamental understanding of this cellular process.



Mathematical Modeling of Nitric Oxide Dynamics in Cerebral Microvascular Networks

Authors: Mahsa Saadat, Asad Mirza and Nikolaos Tsoukias
Faculty Advisor: Dr. Nikolaos Tsoukias

Nitric oxide (NO) plays a vital role as a signaling molecule in the vascular system, where it helps regulate blood flow and maintain vascular tone. Within the cerebral microvasculature, calcium (Ca^{2+}) transients in capillary endothelial cells (cECs) trigger localized NO production, which may influence nearby capillary pericytes and arteriolar smooth muscle cells to modulate blood flow. However, NO bioavailability is limited by rapid scavenging by hemoglobin in red blood cells (RBCs). To better understand the dynamics of NO transport and its impact on blood flow regulation, we developed a mathematical model of NO biotransport within a reconstructed 3D microvascular network comprising 15,000 vessel segments. By incorporating stochastic simulations of Ca^{2+} dynamics in cECs, we modeled sporadic NO release events. The Green's function method was utilized to solve the diffusion-reaction equation for NO, treating cECs as point sources and RBCs as sinks. This approach allowed for efficient prediction of NO concentration distributions in complex vascular geometries. Preliminary simulations validated the method against finite element simulations, and large-scale simulations in a representative vascular network demonstrated its potential for application to macroscopic tissue volumes. Our findings reveal that NO levels are highly sensitive to the frequency of Ca^{2+} events in cECs, highlighting a potential mechanism for localized blood flow control. This study advances our understanding of how cEC Ca^{2+} signaling influences NO bioavailability and vascular tone in cerebral microvascular networks, offering new insights into the regulation of blood flow in the brain.

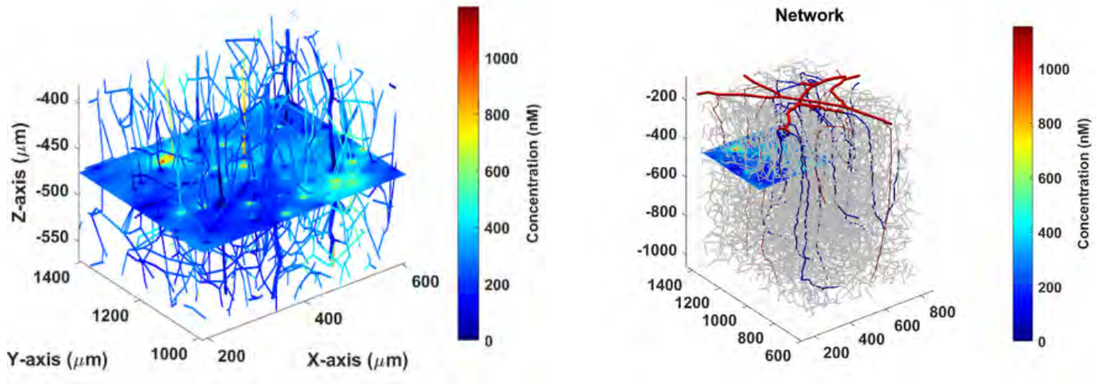


Fig 1. NO release by brain capillaries a. at surface plane -475 μm. b. NO concentration within the network

Production of Cardioprotective Extracellular Vesicles via Dynamic Culture of Mesenchymal Stem Cells

Authors: Manuel Perez-Nevarez, Yih-Mei Lin, Claudia Ponce-Aportela, Mohammad Shaver, Md Golam Sabbir Sarker, Joong Ho Moon, Sharan Ramaswamy and Joshua Hutcheson

Faculty Advisor: Dr. Joshua Hutcheson

Acute myocardial infarction is a leading global cause of death, prompting investigation into mesenchymal stem cell (MSC) therapy as a treatment for damaged cardiac tissues. Recent studies suggest the therapeutic effects of MSCs are mediated by extracellular vesicles (EVs), which protect injured cardiomyocytes. However, low EV yields from small-scale cultures hinder clinical translation. To address this, we hypothesized that dynamic shear forces applied to MSCs could enhance EV production and cardioprotective cytokine expression.

Using a U-shaped bioreactor and pulsatile flow regimens, MSCs were exposed to two dynamic conditions: 0.2 OSI pulsatile flow and 0.5 OSI oscillatory flow, compared to static culture. Dynamic regimens increased total protein production (14X and 19X for 0.2 and 0.5 OSI, respectively) and EV particle yields (78X and 23X, respectively). The 0.2 OSI regimen produced the highest EV particle count (6.8E+12) while the 0.5 OSI regimen yielded the most total protein. Cytokine analysis revealed that IGF-1 and MCP-1 levels were significantly higher under dynamic conditioning, with the 0.2 OSI regimen enhancing both cytokines and the 0.5 OSI regimen primarily upregulating MCP-1. IGF-1 supports cardiomyocyte homeostasis, while MCP-1 mitigates hypoxia-induced apoptosis. These findings suggest that shear stress promotes IGF-1 expression, while oscillatory flow influences MCP-1 upregulation. Dynamic culture effectively enhances EV production and cardioprotective cytokine cargo, offering a promising strategy for scaling EV yields and advancing therapeutic applications for myocardial infarction.

Figure: U-shaped bioreactor chamber used for dynamic-flow conditioning of MSC cells.

Early electrographic biomarkers for epilepsy in a mouse model of repetitive diffuse traumatic brain injury

Authors: Md Adil Arman, Pritom Kumar Saha, Biswajit Maharathi, Stefanie Robel and Oleksii Shandra

Faculty Advisor: Dr. Oleksii Shandra

Post-traumatic epilepsy (PTE) remains a major public health challenge, with all therapies being symptomatic and injury severity the primary risk factor. The lack of reliable biomarkers complicates treatment stratification. We hypothesized that longitudinal, automated power spectrum analysis of continuous EEG data could identify signatures of post-traumatic epileptogenesis in mice after repetitive diffuse traumatic brain injury (rdTBI). Using an impact acceleration model in 12– 16-week-old male mice, we induced rdTBI, mimicking key features of human non-lesional TBI. Continuous video-EEG monitoring for up to four months assessed seizure onset and power spectrum changes compared to sham controls. Out of 28 mice, 7 (25%) developed spontaneous, chronic seizures (PTE+ mice) , averaging onset at two months post-TBI. PTE+ mice exhibited lower delta, theta, alpha, and beta, suggesting progressive cortical network disruptions. Gamma band power remained consistently decreased in PTE groups compared to SHAM and TBI throughout, while high-frequency oscillations (HFO, 80–250 Hz) peaked at weeks 2, 5, and 8. The reduced gamma-to-HFO ratio in PTE mice indicated a shift toward hyperexcitability, with HFO activity dominating over physiological gamma frequencies. The higher occurrence of pathological HFO (pHFO, 250–500 Hz) in PTE+ animals was significant, reflecting focal and network hyperexcitability associated with epileptogenesis. Importantly, delta-coupled pHFO, a strong precursor to epileptic seizures, was identified in PTE animals, suggesting its potential as an early biomarker for PTE after rdTBI. PTE+ mice exhibited distinct EEG changes within the first two weeks of the latent phase. Notably, all of the PTE+ mice had seizures during light hours, with 42.86% occurring exclusively in this period, indicating circadian seizure patterns. These findings highlight potential biomarkers for early PTE detection and therapeutic intervention following TBI.

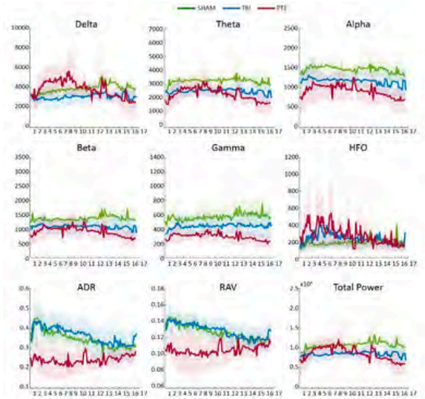


Fig 1. EEG Power Spectrum for 17 weeks

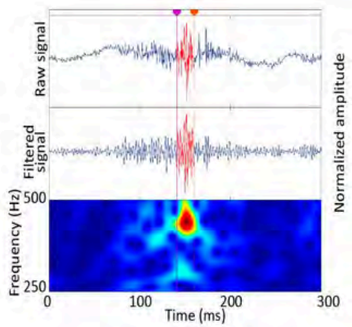


Fig 2: Typical Example of Fast Ripples

Stochastic Simulation of IP3R-Driven Calcium Signaling in Brain Capillary Endothelial Cells

Authors: Niloufar Khakpour, Asad Mirza and Nikolaos Tsoukias

Faculty Advisor: Dr. Nikolaos Tsoukias

Cerebral blood flow regulation ensures oxygen and nutrient delivery to active neurons and is often impaired in neurodegenerative disorders like Alzheimer's and Dementia. Endothelial Ca^{2+} signaling plays a key role by triggering vasoactive substance release, such as nitric oxide (NO), to modulate vascular tone. Recent studies (Longden et al., 2021) highlight high Ca^{2+} activity in brain capillary endothelial cells (cECs), regulated by transmembrane currents (e.g., NSC channels) and intracellular Ca^{2+} release via IP3 receptors (IP3Rs). IP3Rs mediate Ca^{2+} release from the ER through IP3 binding and Ca^{2+}-induced Ca^{2+} release (CICR) but are also inhibited by high intracellular Ca^{2+} as a negative feedback mechanism. This study integrates a stochastic IP3R model with an existing cEC Ca^{2+} dynamics model to investigate Ca^{2+} signaling mechanisms. A modified cEC electrophysiology and Ca^{2+} dynamics model (Silva, Kapela et al., 2007; Moshkforoush et al., 2020) incorporates stochastic IP3R openings. A cEC subdomain includes an ER section with 20 IP3R channels, while key components such as NSC, KIR, KATP, PMCA, and SERCA are scaled by subdomain-to-cell volume ratios. IP3Rs follow the DeYoung-Keizer formalism, with three independent subunits (m: IP3-activated, n: Ca^{2+}-activated, h: Ca^{2+}-inhibited), forming 9N two-state gates. Their dynamics are modeled using a four-state Continuous Time Markov Chain, with kinetics tuned to match experimental IP3R activity (Foskett et al., 2007). A fast kinetics assumption for the m-gate and stochastic Langevin approximations for n and h-gates enable efficient large-scale simulations in a 104-EC cerebral microvascular network. Simulations show that stochastic IP3R openings generate robust Ca^{2+} events, matching experimental data (Longden et al., 2021). These events arise from stochastic m and h gate openings, triggering CICR and transient Ca^{2+} surges. High Ca^{2+} levels inhibit IP3Rs, terminating events. The model also supports electro-calcium coupling, where membrane hyperpolarization increases NSC-mediated Ca^{2+} influx, raising IP3R open probability and enhancing Ca^{2+} store recharging. This leads to a higher prevalence of Ca^{2+} events in capillaries, reinforcing experimental findings on electrical and Ca^{2+} signaling interactions in the cerebral microvasculature.

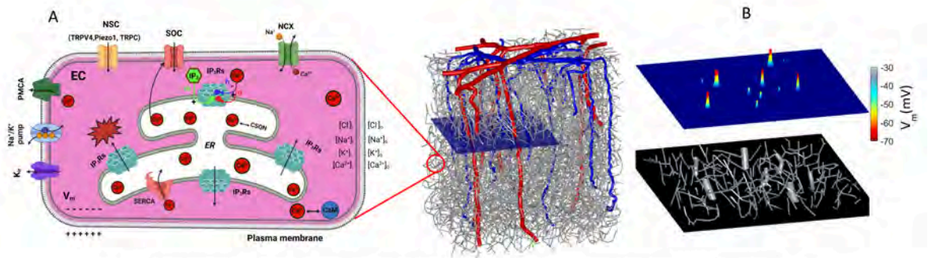


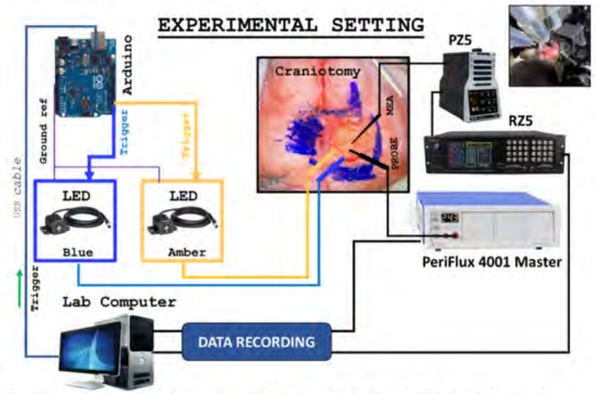
Figure 1. Mathematical modeling of electrical and calcium signaling in the cerebral microcirculation. A) A multicellular model examines electrical and Ca^{2+} dynamics and their propagation in a reconstructed cerebral microvascular network containing 10^4 capillary ECs. (B) Cumulative Ca^{2+} activity over one minute of simulation

The effects of gliotransmission on neuronal electrical activity and related energetics

Authors: Nina Perrotti, Alejandro Suarez and Jorge Riera

Faculty Advisor: Dr. Jorge Riera

Astrocytes have been proposed to regulate synaptic activity by releasing gliotransmitters that assist in neuronal network activations. Also, these cells potentially control optimal energetic supplies associated with gliotransmission by releasing vasoactive substances, adjusting regional blood flow. Both releasing mechanisms are triggered uniquely by calcium activity in astrocytes (Savtchouk and Volterra, 2018). Proofs of neuronal response to gliotransmitters has been limited to in situ electrophysiological and in vivo behavioral measurements (Fiacco and McCarthy, 2018). Energetic demand linked to gliotransmission has yet to be determined. Direct observations of neuronal electric activity and blood flow in response to astrocytic calcium spikes are crucial to overcome these limitations; however, there are multiple challenges associated with the isolation of the gliotransmission effect from other cellular activities in the brain. For the first time, we propose the combination of a transgenic mouse with ChR2 only expressed in astrocytes, for use in a light stimulation paradigm, and electrophysiological/LDF measurements in vivo to quantify neuronal activity and blood flow supply evoked by isolated intracellular calcium increase within astrocytes (Figure, Panel A). To evaluate the effect of astrocytic activation on nearby neurons, we first performed only electrophysiological observations from the cortex in an open craniotomy window, recorded using a silicon linear electrode upon optogenetic stimulation of astrocytes. As proposed, optogenetic stimulation generated increases in LFP in a delayed and sustained manner in agreeance with the slower time dynamics of gliotransmission and their spillover aptitude (Panel B left). LFP increase of nearly 200uv was observed by astrocytic intracellular calcium rise activation (Panel B right). MUA activity was also evaluated using a MATLAB spike-sorting software, Wave_clus (Panel C). In the future, we will additionally perform measurements of regional blood flow under the same stimulation paradigm and implore pharmacological manipulations of potential contributors, like extra-synaptic NMDA receptors and gliotransmitter release routes in efforts to highlight some mechanistic pathways by which gliotransmission can influence synaptic activity in vivo.



Flow diagram for the electrophysiological and LDF data collection (*Panel A*)

Virtual Reality Versus Traditional Environments for Arabic Language Learning

Authors: Noble Amadi, Jonathan Cobos-Solis, Wei-Chiang Lin and Melissa Baralt
Faculty Advisor: Dr. Wei-Chiang Lin

Problem Statement: As interest in innovative language-learning methods grows, the effectiveness of virtual reality (VR) environments compared to traditional classroom instruction is not well understood, especially in the context of Arabic language acquisition.

Research Objective: The main goal of this study is to compare the effectiveness of immersive VR learning with traditional classroom methods in enhancing Arabic vocabulary acquisition and retention. The findings aim to offer insights into the most effective instructional strategies for second language learning. Additionally, a secondary objective is to use functional near-infrared spectroscopy (fNIRS) to examine any potential neurocognitive differences that may explain the observed improvements in learning.

Research Methodology: Twelve participants with no prior knowledge of Arabic language were recruited for this pilot study. Six participants were assigned to learn Arabic in a VR environment (VR Group), while the remaining six learned in a traditional classroom environment (Traditional Group). Initially, all participants took receptive and productive tests (Pretests) to assess their Arabic language abilities. After the pretests, participants engaged in a learning lesson tailored to their respective environments. Finally, participants completed another set of receptive and productive tests (Posttests). Throughout the study, fNIRS signals were recorded from each participant. Statistical analyses were conducted on the scores from Pretests and Posttests to evaluate the effectiveness of Arabic language acquisition in each learning environment. The recorded fNIRS signals were then segmented and analyzed using a custom pipeline to identify changes in regional brain activities during Pretests and Posttests and to compare these changes between the two learning environments.

Results/Conclusions: The analysis of the Pretests and Posttests scores indicate all participants show measurable Arabic language acquisition after the learning lesson. The improvement in the productive test scores from the VR group, however, is significantly stronger than that from the Traditional Group. The fNIRS data analysis showed significant differences in regional brain activities between two groups during Posttests, indicating that VR-based instruction may engage neural regions associated with language production more effectively.

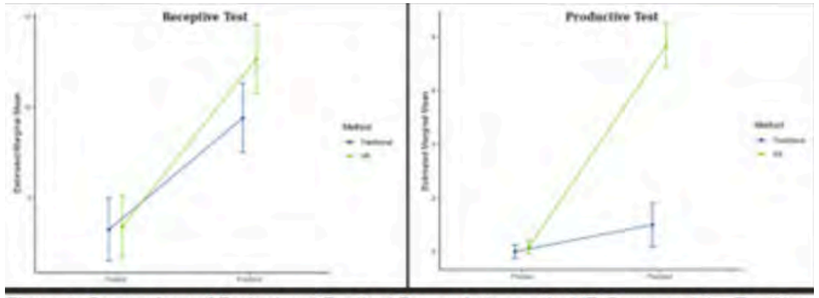


Figure 1: Comparison of Pretest and Posttest Scores between the VR Group and the Traditiona Group. The differences in scores between the Pretest and Posttest are statistically significant fo both groups. Additionally, the improvement in productive test scores for the VR Group i significantly higher than that of the Traditional Group.

Decoder and Neuron Analysis with jaBCI Model

Author: Pedro Alcolea
Faculty Advisor: Dr. Zachary Danziger

Most intracortical brain-computer interface (iBCI) decoders translate neural activity into a continuum of possible velocities ("continuous velocity" decoding). We hypothesized that constraining velocity commands to a discrete set of directions would improve performance by simplifying cursor control. To test this, we developed the discrete direction selection (DDS) decoder, which limits decoded cursor velocity to the four cardinal directions or stopping. We demonstrated that DDS outperforms traditional continuous velocity decoders. User performance was assessed using the joint-angle BCI (jaBCI), a human-in-the-loop iBCI model (Awasthi et al. 2022), and a monkey using an iBCI. In the jaBCI model, 48 human subjects across four visits used one of four decoders: (1) the velocity Kalman filter (vKF, Wu et al. 2002), (2) the ReFIT decoder (Gilja et al. 2012), (3) a population vector decoder with assisted calibration (DR-A, Inoue et al. 2018), and (4) DDS. DDS users performed best, hitting 93% of targets compared to 56%, 39%, and 26% for DR-A, ReFIT, and vKF, respectively (ANOVA $p < 0.001$). In a follow-up study, a monkey alternated between DDS and the Wiener filter (WF, Wu et al. 2006) over seven days. DDS users hit 61% of targets versus 37% with WF ($p < 0.001$, two-tailed paired t-test). Both studies used a 2D, 8-target center-out task, and DDS consistently resulted in faster target acquisition. While the exact reason for DDS's superior performance remains unclear, analysis suggests it stabilizes cursor movement by reducing unnecessary turns, path tortuosity, and velocity fluctuations. This implies that discrete control may be preferable for continuous tasks, as small neural fluctuations are less likely to affect movement commands. Thus, DDS challenges the assumption that continuous velocity decoding is optimal for iBCI cursor control.

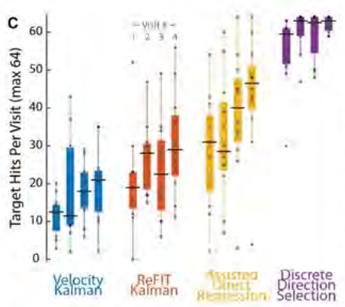


Figure 1: Boxplots of number of targets hit in the center-out task out of 64 possible, outer grouping by decoder used (color) and inner grouping by visit number. Performance increased with repeated visits and varied with the decoder (DDS being the best performers). Dots are individual subjects, black bars are the median, solid box is the interquartile range, and whiskers extend to 1.5 s.d. ± of the mean.

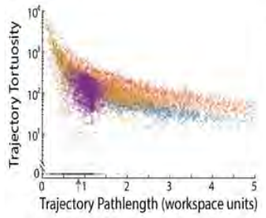


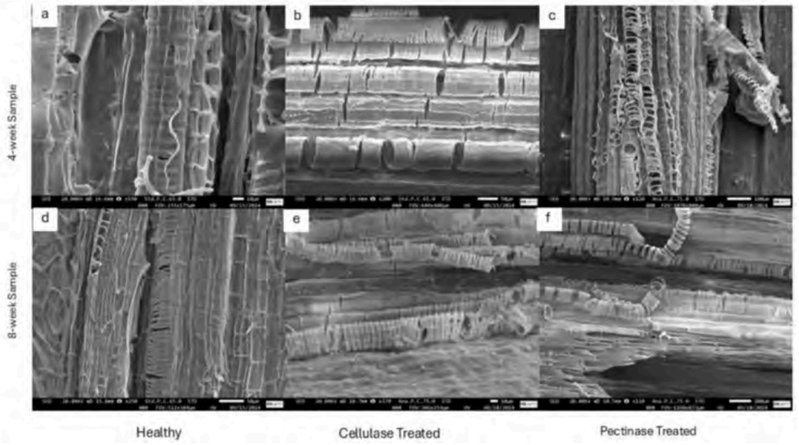
Figure 2: Trajectory pathlength versus trajectory tortuosity (integrated instantaneous curvature change normalized by pathlength) shows DDS subjects executed shorter and spatially simpler trajectories than other groups. The occasional sharp turns in DDS trajectories generated tortuosity similar to the smooth and simple arcs of vKF trajectories, although they're typically shorter. ReFIT trajectories contained the most erratic changes in direction.

Unveiling the Secrets of Plant Vascular Cell Walls: Insights for Bioinspired Biomaterial Design

Authors: Salman Jamal and Anamika Prasad

Faculty Advisor: Dr. Anamika Prasad

Plant vascular cell walls are remarkable structures that play a vital role in the growth, development, and function of plants. These cell walls contribute to diverse aspects, including defense, support, nutrient and ion conduction, and more. Interestingly, the intricate design of plant cell walls has inspired researchers to explore their potential as templates for bioinspired biomaterials. In this study, we investigated the transition from primary to secondary cell walls and the resulting changes in the cell wall's mechanical properties. Using enzymatic treatments, we selectively removed specific cell wall constituents from xylem structure and characterized them at different growth stages using advanced techniques like Raman spectroscopy, SEM imaging, and Nanoindentation. The SEM images revealed thicker cell walls in the mature xylem region, confirming the selective modifications from the enzymatic treatments. Raman spectroscopy analysis further identified the presence of carbohydrate bonds representing cellulosic and hemi cellulosic materials at various growth stages. Nanoindentation evaluation of the mechanical properties, such as elastic modulus and hardness, suggested that pectin and lignin play crucial roles in shaping the cell wall design at different stage of plant's growth. Importantly, the dynamic changes in the cell wall's constituent components significantly influenced its overall mechanical performance. This study provides valuable insights into the structural and functional intricacies of plant cell walls, offering inspiration for the development of innovative bioinspired biomaterials.

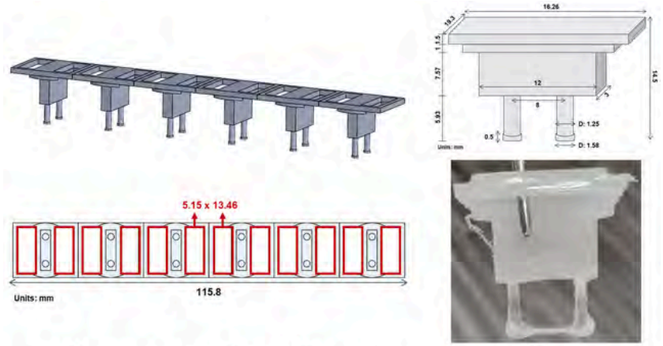


Impact of Stiffness and Viscoelasticity on Hydrogel-Based Engineered Heart Tissue (EHT)

Authors: Yih-Mei Lin, Jorge Riera and Darryl Dickerson

Faculty Advisors: Dr. Jorge Riera and Dr. Darryl Dickerson

Myocardial infarction (MI) is one of the life-threatening causes of death worldwide. In contrast to other organs in the body, heart is limited in regenerative capacity owing to the low renewal rate of CM and lack of CM proliferation. As such, the replenishment to compensate CM loss is difficult to overcome when ischemic myocardial damage occurs. The loss of structural and functional properties of myocardium eventually contributes to ventricular remodeling that leads to the heart failure. Hence, there is a need to overcome the burden and relieve the progression of MI development. Human induced pluripotent stem cells (iPSC) technology has evolved during the past two decades. iPSC and its derivatives have been an emerging field where it offers remarkable therapeutic applications in disease modeling, drug discovery, cell therapy, precision medicine, and regenerative medicine. iPSC holds advantages over primary cells such as easy accessibility from human origin, indefinite expandability, patient-specific, and can be differentiated into almost all types of cells. Cardiomyocytes differentiated from iPSC (iPSC-CM) is an effective candidate for in vitro model for cardiac disease modeling and therapeutic discovery. However, the application of iPSC-CM encountered several challenges including immaturity and lack of scalability. Hydrogel-based, three-dimensioned (3D) engineered heart tissue (EHT) may overcome the limitations and be feasible to recapitulate features of native myocardium. Hydrogel systems can be tuned to form similar biophysical properties to the in vivo environment such as stiffness within physiologically-relevant range, viscoelasticity, aligned architecture, and mechanical forces that regulates cellular behavior. Thus, this study seeks to design a 3D hydrogel platform with modified stiffness and viscoelasticity and investigate the impact on iPSC-CM maturation and proliferation, and further identify the importance of advancing EHT fabrication procedures.



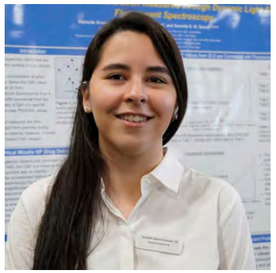
PDMS pillars platform design and hydrogel network on the PDMS pillars

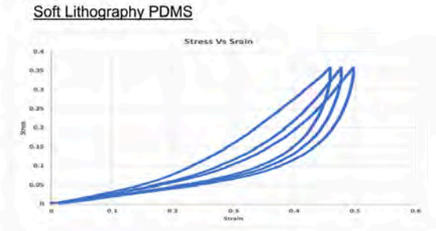
Construction of 3D Porous Scaffolds Utilizing Filament Printing and Soft-lithography

Authors: Basil Usama Hamed, Rachelle Gomez-Guevara, Vivek Kamat, Shakar Bhansali, Juan Pretell and Anamika Prasad

Faculty Advisor: Dr. Anamika Prasad

Large bone defects can arise from various causes such as trauma, autoimmune and aging-related diseases, tumor resection, and surgical complications. Collectively, bone defects impose a substantial financial burden on the healthcare system, exceeding 60 billion dollars, and necessitate an estimated 1.6 million bone graft procedures each year [1]. Technologies such as extrusion-based and stereolithographic-based 3D bioprinting, which can incorporate viable cells offer the potential to fabricate biologically active parts or tissue scaffolds that can mimic the mechanical and physiological characteristics of native tissues. The use of scaffolds would provide better biocompatibility and reduced mechanical failure that occurs utilizing implants and be a superior solution for growing bone such as in pediatric and young adults. This study aims to create 3D porous bone scaffolds utilizing filament printing and soft-lithography to eventually shift to biological material that can then be implanted into the body. The filament-printed porous structure was designed using a custom node group in Blender and then modified in SolidWorks to meet the targeted large bone dimensions (10cm and 5cm). The structure was then printed utilizing an AnkerMake filament printer with polylactic acid (PLA). The soft-lithography porous structure was created by mixing a PDMS base and a curing agent at a 10:1 ratio; this mixture was then poured over a sugar template where sugar molecules act as sites for pores. This mixture was cured overnight, and after dissolution of sugar in warm water resulted in a porous PDMS scaffold. These two differently developed 3D structures were successfully created and characterized via imaging for pore size and pore density, as well as compression testing for mechanical properties. Ongoing and future experimentation is looking into improvements in geometry and effects of printing parameters (humidity and temperature) and related characterization.



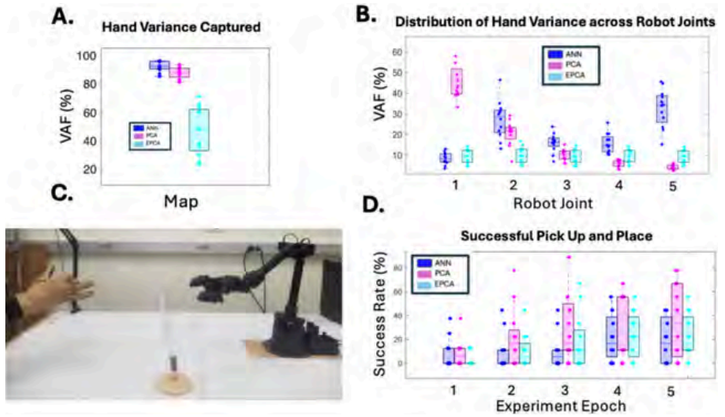


Investigating Factors Underlying Skill Acquisition in High-Dimensional Control of Assistive Robots

Authors: Steafan Khan and Zachary Danziger

Faculty Advisor: Dr. Zachary Danziger

To improve the capabilities of paralyzed people it is often possible to give them control of an assistive robot arm by harnessing any high-dimensional signals they can reliably modulate (e.g., neural activity, muscle activity, or residual movement kinematics). But learning to control a robot using high-dimensional signals is challenging and performance outcomes have been variable. To improve performance in these systems, researchers have begun using artificial neural networks (ANNs) to link user's high-dimensional inputs to robot commands; in place of simpler linear maps. ANNs can differ from linear maps both in terms of how much variance (e.g., information) from the user's high-dimensional inputs they capture and how they distribute that captured variance across robot degrees of freedom. Here we investigate 1) what performance gains are achieved by transitioning to ANNs, if any, and 2) what aspects of ANNs are responsible for improved performance. We recruited 36 participants and provided each control of a 5 DOF robot arm using maps constructed via 1 of 3 algorithms 1) an ANN, 2) Principal Components Analysis (PCA), or 3) our novel Egalitarian Principal Components Analysis (EPCA). Although our maps were starkly different with regards to variance capture and distribution of variance; surprisingly, we found no performance differences between our groups. Our findings suggest that the human machine interface field shifts its focus from the map to other aspects of the interface. Our ongoing work examines the role of control mode (i.e., robot variables directly controlled by the user) on skill acquisition.



ABOUT OUR PROGRAM AND COLLEGE

The Department of Biomedical Engineering at Florida International University (FIU), located in Miami, is committed to preparing ambitious students who want to combine their love of problem-solving with their desire to help others through a fascinating and growing field that applies cutting-edge technologies and modern engineering techniques to improve healthcare.

Our College of Engineering and Computing is ranked #1 for bachelor's degrees awarded to Hispanics*, #1 for Bachelor's degrees awarded to Underrepresented minorities by total*, #1 for master's degrees awarded to underrepresented minorities by total*, and our department is ranked #59 among graduate programs in the country*. Florida International University is designated a Carnegie Highest Research (R1) and Carnegie Community Engaged Institution.

** U.S. News and World BME Graduate Program Ranking (2024 Edition)*
** ASEE (American Society for Engineering Education) Engineering and Engineering Technology: By the Numbers (2023 Edition)*