FIU

Biomedical Engineering
Florida International University

6th Annual Graduate Research Day

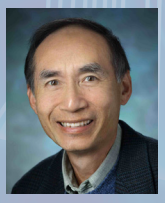
Friday, November 4, 2016

Program:

10:00 am	Seminar: Daniel Catron, MS, MBA (EC 2300) **"Invention to Application – Moving Ideas Out of the Lab and Into Your Startup"**
11:30 am	Lunch Reception (EC 2300)
12:00 pm	Graduate Student Poster Presentation (Panther Pit)
4:00 pm	Seminar: Leslie Tung, Ph.D. (EC 2300) **"Engineered Heart Slices as Models of Human Myocardial Function"**
5:30 pm	Award Ceremony (EC 2300)

Keynote Speakers:

Daniel Catron, MS, MBA
Sr. Licensing Associate
Office of Technology Transfer
University of Miami



Leslie Tung, Ph.D.
Professor and Interim Director
Department of Biomedical Engineering
Johns Hopkins University

Presented by:
Wallace H. Coulter Biomedical Engineering Distinguished Lecture Series
FIU Department of Biomedical Engineering

For more information: bme@fiu.edu | p. 305-348-6950 | bme.fiu.edu

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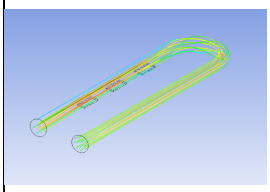
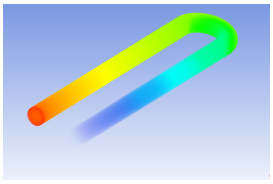
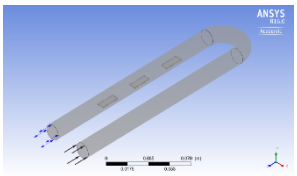
Computation of Shear Stress Oscillations in Physiological Conditions - Implications to Valve Tissue Growth

Authors

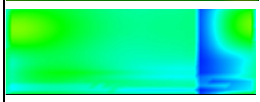
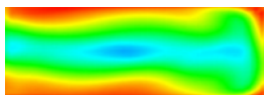
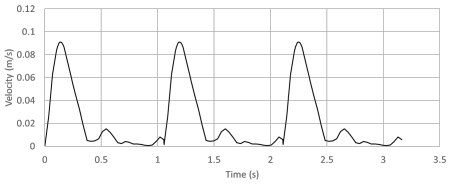
Alex Williams, Manuel Perez, Arash Moshkforoush, Omkar Mankame, Manuel Salinas, Nikolaos Tsoukias, Sharan Ramaswamy

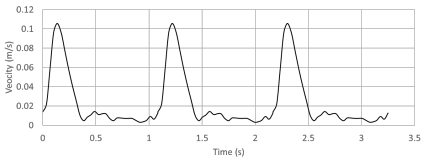
Major Adviser Dr. Sharan Ramaswamy

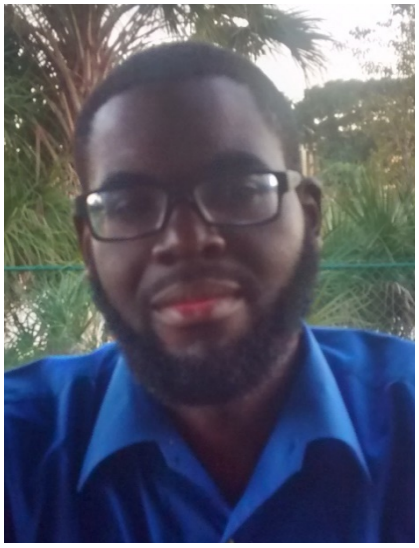




$$OSI = 0.5\left(1 - \frac{\int_0^T |WSS|}{\left|\int_0^T WSS\right|}\right)$$







Abstract

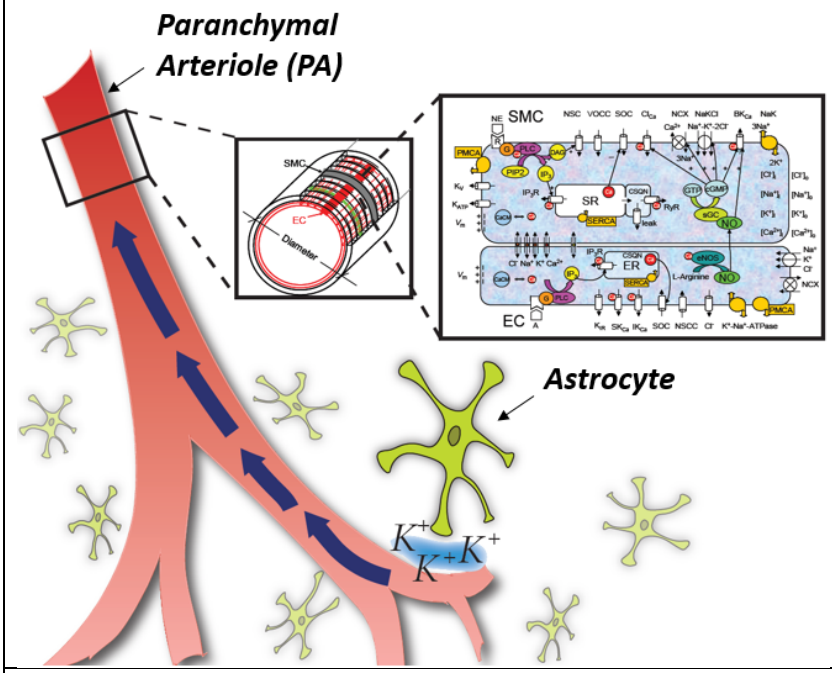
Fluid-flow induced shear stress has been shown to influence collagen formation in in the growth of engineered tissues. Previous studies examined collagen formation in engineered tissue under static flow, steady-state flow, pulsatile square-wave flow, cyclic flexure as well as combined cyclic flexure and steady-state flow simulations. These conditions, however, do not fully represent cardiac pulses experienced by native cardiovascular tissues. This study examined collagen development in engineered tissue by subjecting samples to flow regimes that more closely mimic pulsatile physiological conditions. A bioreactor was used to simulate in-vivo conditions experienced by engineered tissue using rectangular strips of specimens immersed in flow media. Computational fluid dynamics (CFD) software was used to analyze flow physics and flow characteristics around the specimens. Computational findings were compared to previous tissue engineering studies conducted in our own laboratory. ANSYS computational fluid dynamics software was utilized in performing CFD simulations and modelling flow parameters and flow physics under viscous laminar flow within the chamber. Such CFD simulations applied arterial-based waveforms from regions such as the aorta and pulmonary artery while utilizing the bioreactor geometry, which consisted of a U-shaped tubular conditioning chamber that houses the tissue samples and through which flow media was pumped across the face of the tissue samples.

Inward Rectifying Potassium Channels and Spreading Vasodilation in the Cerebral Vasculature

Authors

Arash Moshkforoush, Nikolaos M. Tsoukias

Major Adviser: Nikolaos M. Tsoukias



Abstract

The vasodilatory effect of extracellular potassium ions, and their role in increasing local Cerebral Blood Flow (CBF), has been extensively shown in literature. They have been widely reported as one of the key mediators of Neurovascular Coupling (NVC). Recently, inward rectifying potassium (K_{ir}) channels in the vascular wall have been proposed as ideal candidates to sense changes in the extracellular potassium concentrations ($[K^+]_o$) resulting from neuronal activity, and to transmit vasodilatory signals to upstream parenchymal arterioles (PAs).

Here, we present a multi-scale mathematical modeling approach to shed light on the role of K_{ir} channels in mediating NVC. The outlined approach can provide a useful platform in which the regulation of blood flow in cerebral vasculature, both in normal and diseased states, can be analyzed by integrating underlying mechanisms at cellular and molecular levels. Single cell models (i.e. endothelial (EC) and smooth muscle (SMC)) are constructed to predict the dynamics of major ionic species and membrane potential (V_m) at the whole cell level via integrating detailed mathematical expressions for ionic channels and intracellular components. A model vascular network is formed by electrically coupling the cells and placing them in proper arrangement.

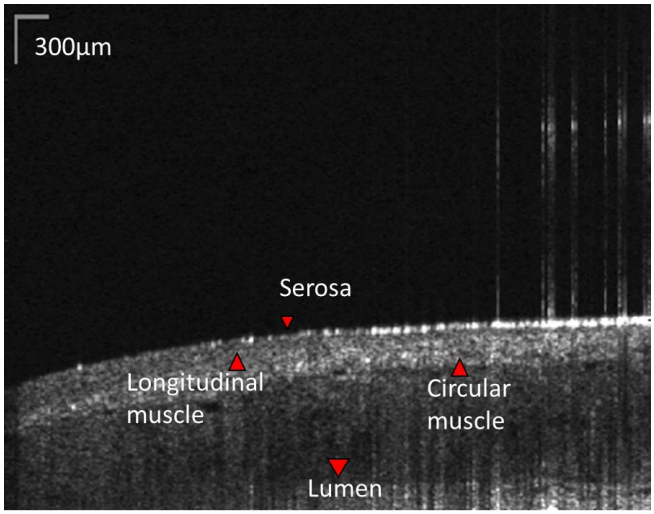
We examined how K^+ release at the astrocytic endfeet can lead to upstream hyperpolarization and dilation of PAs. Model simulations suggest unique dynamics of ECs with a dominant Kir current as a result of the nonlinear current-voltage relationship of this channel. An increase in $[K^+]_o$ leads to an abrupt transition of EC V_m to a hyperpolarized state as a result of a saddle-node bifurcation. The presence of a V_m bistability over a range of $[K^+]_o$ is predicted. It can lead to self-amplifying conducted hyperpolarizations, a highly efficient mechanism of spreading vasodilation. This regenerative mechanism is conditional to the relative ratio of Kir channel conductance (G_{Kir}), to total background conductance (G_{bg}).

Investigating small intestine neuromuscular anatomy using optical imaging

Authors

Ashfaq Ahmed, Yuqiang Bai, Jefferson Gomes, Jessica C. Ramella-Roman, and Ranu Jung

Major Adviser: Dr. Ranu Jung



Abstract

The innervation of the gut is comprised of an extrinsic (autonomic) nervous system and an intrinsic nervous system. Intestinal tract electrical stimulation can influence gastric motility. In order to target specific layers of the intestinal mucosa and understand neural control mechanisms, *in-vitro* preparations of excised rat intestine have been used. For *in-vivo* stimulation in intact preparations, novel approaches will be required to identify the neuroanatomical targets for electrode placement. We used two optical imaging approaches to identify the different layers of rat small intestine and cross-validated the images with conventional histology. Duodenum and jejunum-ileum intestine samples were obtained from euthanized male Sprague-Dawley rats weighing 300 gm and 6-8 weeks old. 10µm paraffin embedded sections were stained with Hematoxylin & Eosin (H&E) while 10µm cryostat sections were H&E and Nissl stained. Muscle layers were clearly identifiable and the thickness of muscle layers (longitudinal muscle layer and circular muscle layer) and neuron layers (myenteric plexus and submucosal plexus) was measured and compared in the duodenum and jejunum-ileum.

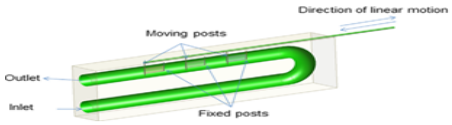
The same sections were also examined using nonlinear optical microscopy that combines two-photon fluorescence (where the sample is excited by low energetic photons (800 nm) and high energetic photons (520 nm) are emitted by fluorescence) and second harmonic generation (where the emission wavelength is half the excitation wavelength (800 nm)). The optical images obtained using two-photon microcopy were co-registered with the stained images. Although the optical imaging could not identify neurons in plexus layers the serosa, longitudinal and circular muscle layers can be clearly identified. From the location of the muscle layers, location of the myenteric plexus neuronal layer can be interpolated since it is sandwiched between the longitudinal and circular muscle layers.

A Comparison of Oscillatory Blood-Induced Shear Stresses on the Surfaces of Normal versus Stenotic Aortic Heart Valves in Infants

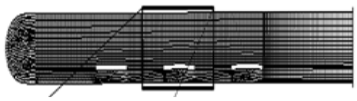
Authors

Elnaz Pour Issa, Alexander T. Williams, Sana Nasim, Arash Moshkforoush, Denise Medina, Lilliam Valdes-Cruz, Steven Bibevski, Frank Scholl, Nikolaos Tsoukias, Sharan Ramaswamy

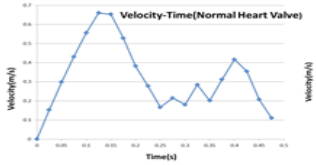
Major Adviser Dr. Sharan Ramaswamy

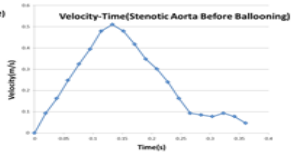


Picture of a single bioreactor chamber connected to a media source.

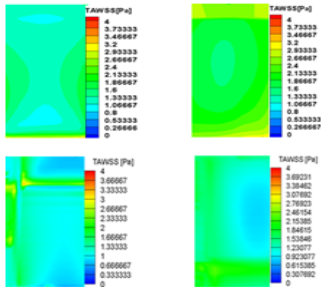


Cross section of the structured mesh with 472728 nodes , and 441370 elements

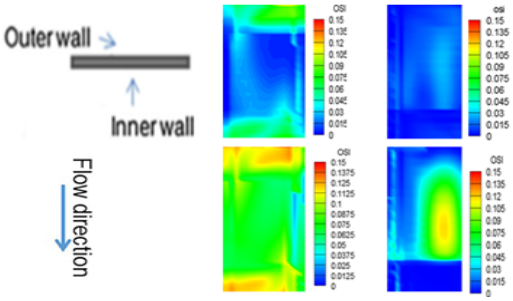




Inlet Velocity Profiles at LVOT(Left Ventricular Outflow Tract) Boundary Conditions



(TAWSS)Time Average Wall Shear Stress



(OSI) Oscillatory Shear Index

Abstract

Cardiovascular pathologies remain a critical issue in medicine. One example of heart valve disease is critical aortic heart valve stenosis (CAHVS). The stenosis pathology in heart valves is closely linked to flow physics within the vessel. The project goal is to computationally compare the flow behavior in normal and stenotic states by running two simulations in a 3D dynamic culture system (i.e., a bioreactor) and introduce a new computational index that may better predict the onset of CAHVS. The velocity data for the two simulations are obtained from an infant with critical aortic stenosis as well as from a normal one. Two computational fluid dynamics simulations (CFD; ANSYS) were conducted for samples virtually mounted within a bioreactor. The pulsatile velocity profiles were prescribed to the inlet, and a zero-pressure profile was specified as the outlet of both stenosis and the normal simulations. The fluid within the simulations was prescribed with blood material properties. The results show that the amount of temporal blood stress on the heart valve is different between the normal and the stenosis case. Shear stress is known to be an important parameter in the engineered tissue formation. In addition to the magnitude of the sheer stress, the direction of wall shear stress varies temporally as well. In order to quantify the changes in direction of wall shear stress (WSS), the oscillatory shear index (OSI) is presented. The OSI distribution was generally found to be higher across the regions of stenosis sample compared to the normal case. We thus interpret that the greater degree of OSI across heart valve leaflets during fetal development may lead to stenosis of the valve at birth.

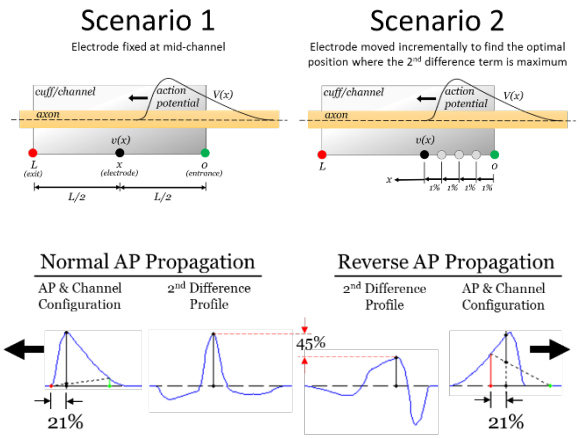
Thus OSI, may serve as a biomechanical regulator of valve health-status, although the specific biological mechanisms that lead to disease are still yet to be determined.

Predicted Effect of Electrode Position on the Amplitude of Recorded Neural Signals Using Cuff-Like Technologies

Authors

iian Black, James Abbas, Ranu Jung

Major Adviser: Ranu Jung



Abstract

Cuff electrodes or microchannel electrode arrays for neural recording are typically designed using a recording electrode positioned at mid-channel. While it has been suggested that an off-center position may enhance the amplitude of recorded signals, a systematic examination of the effect is needed. The purpose of this analysis was to explore the relationship between action potential waveform shape, channel length and electrode position to identify situations where shifting the recording electrode from mid-channel could increase the amplitude of recorded signals.

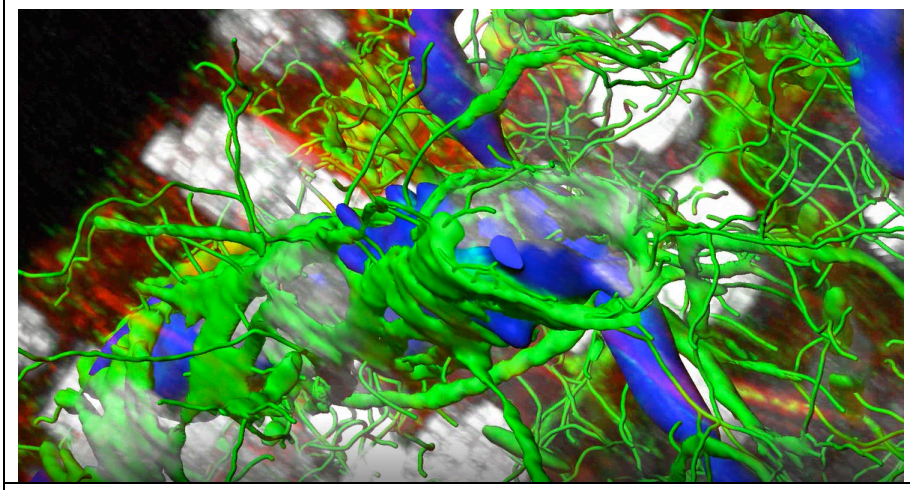
A mathematical model developed by Stein and Pearson (1971) for predicting recorded signal amplitudes in narrow channels was used. Two simulation scenarios were explored for different channel lengths. A first set of simulations computed recorded signals with the electrode fixed at mid-channel. A second set of simulations, varied the position of the recording electrode from the channel entrance to the exit in increments of 1% of the AP wavelength. Three AP waveforms were analyzed. AP waveforms were normalized to 100% of their peak amplitude and 100% of their wavelength. This enabled results to be readily compared between action potentials having different amplitudes and spatial extents.

When channel lengths exceed twice the spatial extent of the rising phase of the AP, an electrode shifted towards the channel exit enhances the amplitude of recorded signals. Recordings of APs traveling in the opposite direction are significantly attenuated.

This analysis suggests that recorded signal amplitudes may be enhanced when the electrode is situated toward the channel exit for certain channel lengths. Action potentials travelling in one direction may be preferentially enhanced and detected over those traveling in the opposite direction. A practical application of this result would be cuff and microchannel electrodes capable of discriminating between efferent and afferent activity in peripheral nerves.

3D Interconnectivity of Cerebral Cortex

Authors
Jared Leichner
Major Adviser **Wei-Chiang Lin**



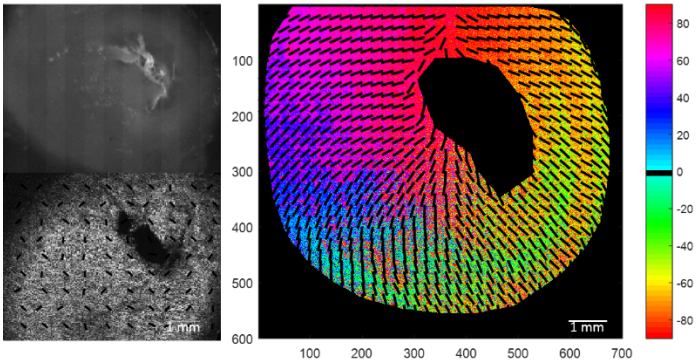
Abstract
Macro, Micro and Molecular-scale analyses are essential to understand the complex cortical networks and their alterations in brain tissue. Within the cortex, numerous cell types in the brain interconnect in complex 3D networks to regulate electrical and metabolic activities. By developing a 3D map of cortical tissue interconnectivity that differentiates between various regions of the brain, it will be possible to understand the structural changes that underlie functional differences between brain regions.
Assessing properties of brain tissue in normal and pathological conditions requires an understanding of its hardware (morphological/structural interconnectivity) and software (functional interconnectivity). At this initial stage of examination, only morphological and structural features will be assessed. Morphological connectivity determines the spacing between cell types in the brain, which affects the speed and magnitude of diffusion of functional molecules. Homogeneous cellular connectivity can help understand the activities of neurons (i.e. action potential propagation, neurotransmitter release) and astrocytes (i.e. calcium wave propagation). Heterogeneous cellular connectivity can help understand tissue-level characteristics, such as neurovascular coupling (neuron-vascular communication) and neurometabolic coupling (neuron-astrocyte communication).
My dissertation work has three fundamental objectives:

1. Determine morphological interconnectivity of neurons, astrocytes and vasculature in the cerebral cortex, with emphasis on how this changes between functional areas of the cortex in a normal brain
2. Discovery of novel cell subtypes based upon morphological classifications
3. Assess local, regional and global changes in morphology in disease states such as epilepsy

Use of Mueller Matrix Polarimetry and Optical Coherence Tomography in the characterization of cervical collagen anisotropy

Authors
Joseph Chue-Sang, Yuqiang Bai, Nola Holness, Jessica C. Ramella-Roman

Major Adviser Jessica C. Ramella-Roman



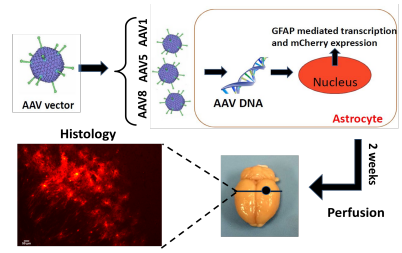
Abstract
Preterm birth (PTB) presents a serious medical heath concern throughout the world. There is a high incidence of PTB in both developed and developing countries ranging from 11%-15%, respectively. Studies have shown there may be numerous precursors to PTB including infections, genetic predisposition, nutrition and various other morbidities which all lead to a premature disorganization in the cervical collagen resulting in the weakening of the structure designed to keep the fetus in utero. The changes in cervical collagen orientation and distribution may prove to be a predictor of PTB. Polarization imaging is an effective means to measure optical anisotropy in birefringent materials such as those rich in collagen as the cervix is. Non-invasive, full-field Mueller Matrix polarimetry (MMP) imaging methodologies and ex-vivo second harmonic generation (SHG) imaging were used to assess cervical collagen content and structure in non-pregnant porcine cervices. The SHG microscopy was used to verify the efficacy of the MMP in assessing changes in collagen orientation.

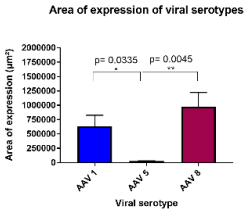
SEROTYPE BASED EVALUATION OF AN OPTOGENETIC CONSTRUCT TARGETING RAT ASTROCYTES

Authors

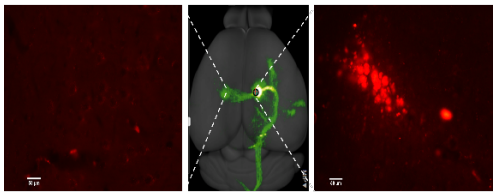
Lakshmini Balachandar, Diana Borrego, Jeremy Chambers, Jorge Riera Diaz

Major Advisor: Dr. Jorge Riera Diaz

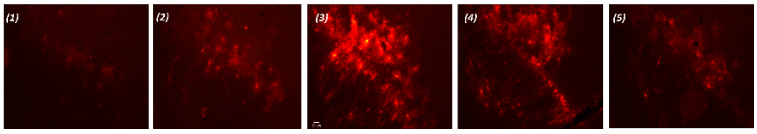




Representation of retrograde expression of the viral vector



Representative images of viral spread of Serotype 8 in the somatosensory cortex



Abstract

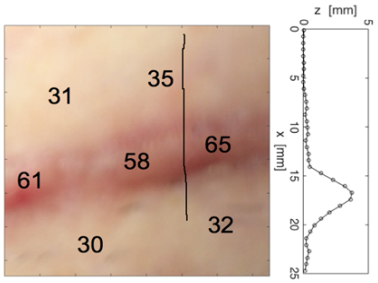
Optogenetics is a modern technique in neuroscience to control excitable cells with light and has recently been used on electrically non excitable cells like astrocytes. This involves introduction of a viral vector with a light sensitive protein which facilitates cationic influx into the astrocyte, upon activation. The viral construct of interest, to target astrocytes in our experiments is AAV-GFAP-hChR2 (H134R)-mCherry. However, to perform transduction in astrocytes, an evaluation of the serotypes of the optogenetic vector is necessary. This research is focused on finding the ideal serotype of the optogenetic virus in an *in vivo* rat model. The plausible serotypes for the study were narrowed down to serotypes 1, 5 and 8, based on previous studies in the spinal cord and the rat brain targeting neurons. This evaluation would help us understand the expression of the gene conferring light sensitivity to the astrocytes, and thereby allowing us to control them using light. The validation of viral expression has been performed by post mortem histological analysis. From the preliminary data, serotype 8 of the virus shows promising transduction patterns in astrocytes in the cerebral cortex, in terms of the highest spread, as well as the largest area of expression in the brain tissue. A retrograde mechanism of shunting of the viral vector has been observed, and serotype 5 has been significantly involved in this mechanism, which to be investigated further. This approach would help gain control of astrocytes, which can be used to study various pathological conditions in the mammalian brain.

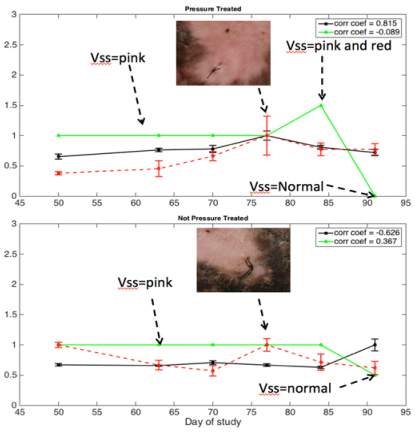
Multimodal Non-invasive System to Ascertain Quantitative Metrics of Scar Formation

Authors

MariaCarla Gonzalez, Nicole Sevilla, Karla Montejo, Joseph Chue-Sang, Shupp JW, Moffatt LT, Ramella-Roman JC

Major Advisor: Jessica Ramella Roman





Abstract

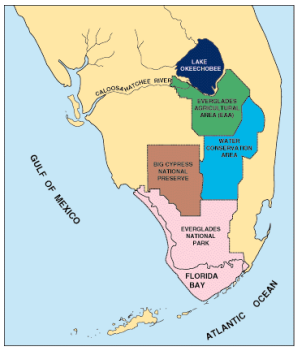
Wounds that result from thermal injury are devastating and the incidence of burn injuries has remained constant worldwide. Burn injuries are the fourth most common type of trauma and the most vulnerable groups are children, women and the elderly. Up to 67% of individuals surviving burn injury will develop debilitating hypertrophic scar, which can cause serious functional limitations, body dysmorphic issues and social reintegration barriers, as well as significantly reduced physical function.[1] Assessment of hypertrophic scars has been based on subjective clinician rankings such as the Vancouver Scar Scale (VSS). This scale was introduced in the nineties and relied on physician evaluation of the four basic scar features: Pigmentation (Normal, Hypopigmentation, Mixed Pigmentation, Hyperpigmentation), Height (Normal, 1-2 mm 2-4, mm, 4-6 mm, >6mm), Vascularity (Normal, Pink, Red, Purple), and Pliability (Normal, Yielding, Firm, Bending, Contracture). The evaluation is carried out by visual and tactile inspection, hence, it is influenced by individuals' interpretation. [2] A multimodal non-invasive system, Spectroscopic Polarimetric Optical System (SPOS), will be used to quantify the four VSS parameters (Color, Vascularity, Height, and Pliability). Combining four methodologies (SFDI, Laser Speckle imaging, Pliability and Metrology) we can therefore ascertain quantitative metrics of scar formation.

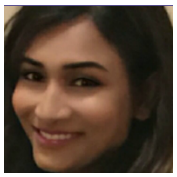
Rapid, On-Site Environmental Phosphate Testing with a Smart Phone: The Solution to a Troubled Everglades

Authors

Mehenur Sarwar

Major Adviser **Chenzhong Li**





Abstract

Phosphates are essential in biochemistry as well as ecology as they are fundamental building blocks of numerous substances, including those used for energy. In the human body, too high of a phosphate level (hyperphosphatemia) and too low of a phosphate level (hypophosphatemia) are dangerous and impede normal functioning. Similarly, in the environment too high of a phosphate level can be extremely detrimental and is often caused by various factors including runoff from agricultural sites, fertilizers, pesticides and detergents.

Phosphate in the water supply stimulates the growth of plankton and aquatic plants, which is a beneficial food source for larger animals. However, imbalance can cause disastrous changes, such as toxic algal blooms and habitat destruction. Currently, there is no simple method to rapidly determine the phosphate level on-site in the relevant range where phosphate levels transition from 'normal' to 'too-high'. Instead, individual samples will be taken into the lab for a time-intensive, laborious and expensive characterization procedure. My goal is to optimize this process through the design of an on-site phosphate testing assay utilizing a smart phone to test a liquid sample. This assay will be rapid, reliable and encompass a linear range that includes the EPA relevant cutoff level within.

Recruiting of Liquid Base 3D Printing Technique for Manufacturing of Aortic Heart Valve

Authors

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Major Adviser: Sharan Ramaswamy

Abstract

Critical congenital aortic heart valve diseases in children have extremely limited treatment options. From a research standpoint, functional, organ-level tissue engineered heart valve (**TEHV**) replacement which would permit longitudinal, valvular growth and would not pose any immune risks in the treatment of pediatric congenital valve disease is thought to be a potentially ideal solution. However manually-assembled valves may not provide with consistent outcomes. With 'form follows function' – thus the bio-mimetic shape and thickness replication of the valve substitute is important. The unloaded leaflet shape will affect the nature of subsequent mechanical stress distribution on the leaflet over the cardiac cycle. Using finite element analysis, the research indicated that a more biomimetic shape for TEHVs enhances and streamlines the distribution of loads across the leaflets although the shape did not have to be an exact match to the native valve. One method that valve shape characteristics can be tightly controlled and replicated is in using 3-dimensional (3-D) printing technologies. In this study we demonstrated that recruiting of the liquid base 3D printing technique for manufacturing the aortic heart valve is feasible.

Early In Vitro Hydrodynamic Evaluation of Porcine Small Intestine Submucosa Heart Valve in the Mitral Position

Authors

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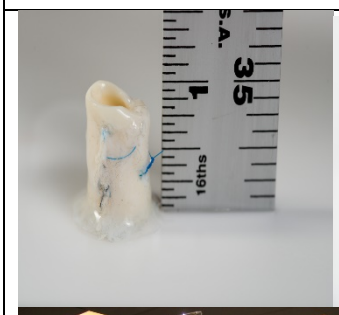
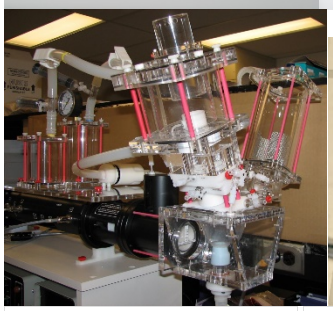
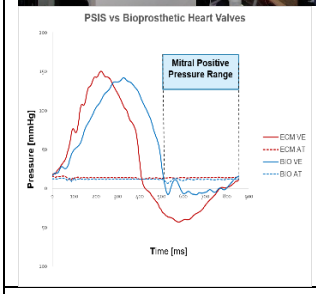
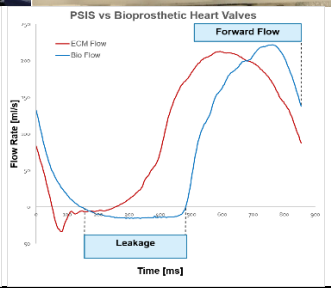








Abstract

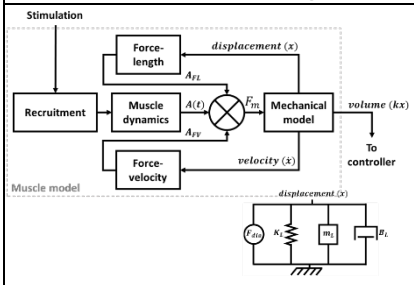
Infants and children with severe valve lesions have limited surgical options. since available prosthetic valves have major limitations in terms of growth potential and longevity. For these patients, valve replacement procedures often result in high morbidity and mortality rates. Porcine Small Intestine Submucosa bioscaffold has shown the ability to recruit native cardiovascular cells, enabling formation of valvular tissue when the substrate degrades. Our group has implanted custom-made PSIS valves in 4 infants with critical valve disease unable to receive standard valves. Also in our previous hydrodynamic evaluation, we demonstrated acute functionality of tri-leaflet aortic PSIS valves and obtained robust flow and pressure parameters which were physiological in nature. The focus in this study was to preliminarily evaluate the efficiency of PSIS bioscaffolds in the mitral position using a left heart simulator in our laboratory. The average flow rate observed in PSIS valves (n =3) was 178.7 ml/s, whereas that obtained from a bioprosthetic valve control group (n =2) was 183.6 ml/s. However, after scaling for differences in effective orifice areas (EOA) between the two groups, higher pressure gradients (↗59%) and energy losses (↗66%) were still observed in the PSIS valves as compared to the control group. We interpret that the EOAs between the two groups need to be more closely configured before the efficiency of PSIS mitral valves can be ascertained. This requires additional hydrodynamic evaluation in the mitral position so that objective results can be obtained, and is currently on-going in our laboratory.

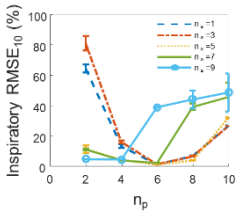
Closed-loop adaptive controller for respiratory pacing in a rodent model

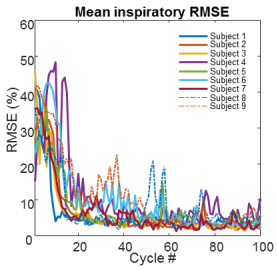
Authors

Ricardo Siu, Brian Hillen, Anil Thota, James Abbas, Sylvie Renaud, and Ranu Jung

Main Advisor: Ranu Jung







Abstract

Spinal cord injury at the cervical level can cause damage to the descending respiratory pathways, which can lead to a significant reduction in ventilatory capabilities. Respiratory pacing via electrical stimulation of the phrenic nerve or of the diaphragm has been shown to enhance quality of life compared to mechanical ventilation. However, commercially-available respiratory pacing devices require initial manual specification of stimulation parameters and frequent adjustment to achieve and maintain suitable ventilation and ventilatory efficiency over long periods of time. We have developed a closed-loop neuromorphic controller capable of meeting the ventilatory demands of the user despite changes in muscle and electrode properties.

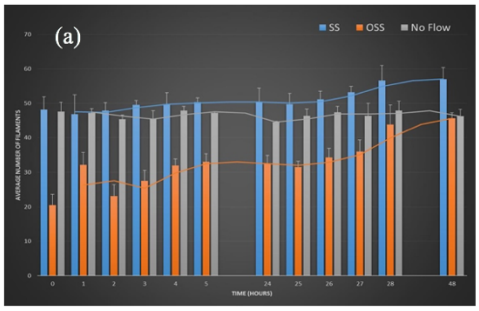
We developed a biomechanical model of the rat diaphragm and implemented the adaptive controller in simulation. These computational studies determined suitable sets of controller parameters over which the controller could achieve and maintain an inspiratory root-mean-squared error (iRMSE) of less than 5% within a period of 20 breathing cycles. Acute animal studies in anesthetized and uninjured rats validated the computational study results by showing satisfactory controller performance. Adaptive controller achieved iRMSE values below 10% within 20 cycles and maintained iRMSE below the 10% target for periods of 100 breathing cycles or more.

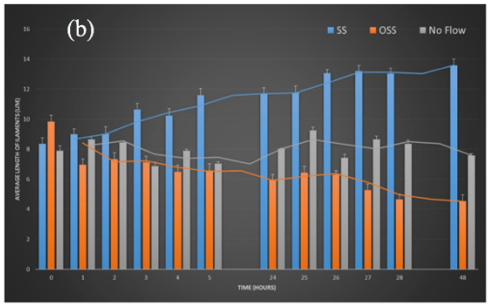
Bone Marrow Stem Cells' Cytoskeletal Reorganization after flow exposure

Authors

Sana Nasim, Denise Medina, Glenda Castellanos, Luis Nassar, Sasmita Rath, Sharan Ramaswamy

Major Adviser: Dr. Sharan Ramaswamy





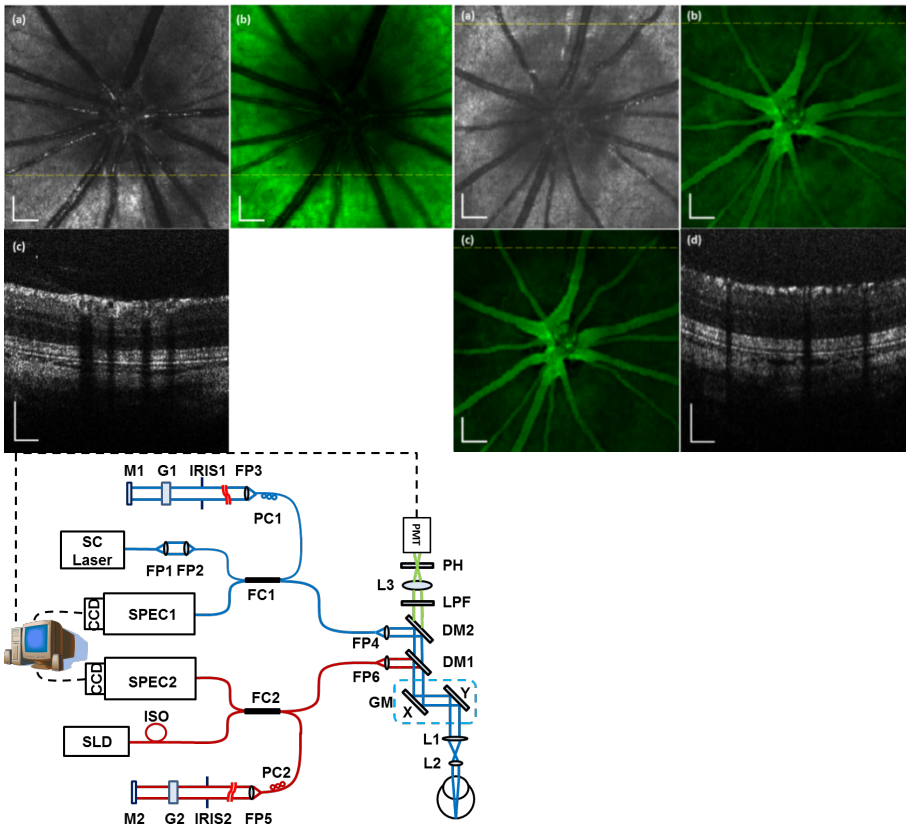
Abstract

Congenital heart valve defects occur in four to six infants for every 1000 births, where critical aortic valve stenosis (AVS) has been one of the life threatening conditions. It results in high mortality and morbidity despite of early intervention. Heart valves experience mechanical stresses including cyclic flexure, tensile, and oscillatory shear stress (OSS) during their lifetime. In this study, we show steady state and OSS affect on structural BMSCs, which has been shown to regulate the proliferation and differentiation of BMSCs. Approximately half a million HBMSCs were grown and transfected with actin in living cells. Transfected BMSCs were plated in Collagen Type I coated microchannels. Three groups of environment were conditioned: no flow, steady state (SS) and oscillatory shear stress (OSS). Images were taken every 5 hours for the first two day using fluorescent microscopy. Cell-structure quantification was done using ImageJ analyses software. BMSCs actin filament increased significantly (p-value < 0.05) in number by 122.6% after 48 hours of OSS, while on the other hand, cells from SS group only increased with 18.2% after 48hrs of exposure. There was a 53.8% decrease in average length of the filament after 48 hours exposed to OSS, while on the other hand there was a 19.5% increase in average filament length on cells exposed to SS. The no flow group demonstrated marginal changes with number of actin filaments and F-actin filament length. In conclusion, we have shown significant differences in SS and OSS groups of actin filament numbers and f-actin filament length. This study reports first steps needed to present how structural cytoskeletal changes in BMSCs after SS and OSS exposure leads to favorable gene expression changes which may support the valvular phenotype.

Visible-light optical coherence tomography-based multimodal retinal imaging for improvement of fluorescent intensity quantification

Authors
Zahra Nafar, Minshan Jiang, Rong Wen, and Shuliang Jiao

Major Adviser Dr. Shuliang Jiao



Abstract

We developed a spectral-domain visible-light optical coherence tomography (VIS-OCT) based multimodal imaging technique which can accomplish simultaneous OCT and fluorescence imaging with a single broadband visible light source. Phantom experiments showed that by using the simultaneously acquired OCT images as a reference the effect of light attenuation on the intensity of the fluorescent images by materials in front of the fluorescent target can be compensated. This capability of the multimodal imaging technique is of high importance for achieving quantification of the true intensities of autofluorescence (AF) imaging of the retina. The retinal AF intensities changes in aging, as well as in certain pathological conditions, such as in AMD and Stargardt diseases. However, the measured AF in an image can be affected by many factors, including the optical properties of the anterior segments of the eye; the intensity of the excitation light; and even alignment of the eye with the excitation light beam. Eliminating the influence of all the factors that are not related to the optical properties of the Retinal Pigmented Epithelium (RPE) would improve the quantification accuracy of AF imaging, which will make it possible to compare the overall AF intensities as well as changes in the spatial distribution of AF.

The proposed multimodal imaging system can simultaneously acquire OCT and AF imaging with a single light source. Since the OCT signals are attenuated by the same media as the AF signals, the OCT signals can be used as an internal reference to compensate the signal attenuation by the media anterior to the RPE. We applied the technique in retinal imaging including AF imaging of the RPE and fluorescein angiography (FA) and we successfully demonstrated the effect of compensation on AF and FA images with the simultaneously acquired VIS-OCT images.