Johns Hopkins Department of Biomedical Engineering





# Tuesday, May 7 • 1:00 pm – 7:00 pm

Armstrong Building • Johns Hopkins School of Medicine





# WELCOME TO BME DESIGN DAY 2019!

The Johns Hopkins Department of Biomedical Engineering is breaking new ground in biomedical discovery and innovation, developing the next generation of disruptive technologies that will transform the practice of medicine and improve human health. As part of our new BME 2.0 curriculum, we are providing students with real engineering experience through project-based courses, specialized instruction in the emerging disciplines of biomedical engineering, and opportunities to pursue clinical, research, and design experiences starting from their first day on campus.

This is an exciting year for BME design. We are celebrating the 10th anniversary of our leading master's degree program in the design of healthcare solutions, operated by the department's Center for Bioengineering Innovation and Design (CBID). Also this year, our undergraduate Design Team program, established in 1998 as the first program of its kind to incorporate freshmen through seniors, began integrating internships into the design curriculum to allow teams of students to work on industry-driven projects over the course of the academic year.

Through these programs, Hopkins BME remains committed to educating the next generation of leaders in healthcare innovation. As a department within both the Whiting School of Engineering and the School of Medicine, we offer students at all levels the opportunity to engage with the world's leading physicians, scientists, and engineers. Each year, we bring together more than 20 teams of BME students, Johns Hopkins clinical and engineering faculty, and external mentors and sponsors to design better solutions to important healthcare challenges. Together, these teams work on projects targeted to both advanced and under-resourced healthcare systems around the world.

Using a unique iterative approach to design, BME students apply their knowledge and skills to real-world challenges. As you glance through the project descriptions in this booklet, you will see the tremendous scope of the Hopkins BME design program, which spans many clinical themes, technology domains, and countries.

We encourage you to speak with these teams throughout the day, and consider joining our program as a student, clinical mentor, business advisor, or financial sponsor. Your participation could provide design teams with the guidance and resources they need to understand problems, develop concepts, and design solutions that have the potential to save lives. Together, we can continue **Engineering the Future of Medicine** and developing the technologies that cure disease.

We would like to thank our wonderful partners, sponsors, and supporters who have guided our students throughout the year. Today we showcase the results of their hard work and dedication. Enjoy your visit.

Sincerely,

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Michael I. Miller Bessie Darling Massey Professor and Director Department of Biomedical Engineering Johns Hopkins University

Youseph Yazdi Executive Director Center for Bioengineering Innovation and Design Johns Hopkins University

# **BME DESIGN DAY AGENDA 2019**

12:30 pm - 1:00 pm	Registration
1:00 pm - 1:15 pm	Introductory Remarks
1:15 pm - 2:00 pm	
	Founder & Executive Chairman,
	Ocular Therapeutix, Inc.

# "Medical Entrepreneurship: Why and How"

2:00 pm – 3:00 pm Healthcare Innovation Presentations: CBID MSE Program
3:00 pm – 3:15 pm Remarks & Break
3:15 pm – 4:30 pm Healthcare Innovation Presentations: Undergraduate Design Team Program
4:30 pm – 5:00 pm Alumni Panel
5:00 pm – 5:30 pm Healthcare Innovation Presentations: Project-based Design Courses
5:30 pm - 6:45 pmPoster Session & Reception
6:45 pm - 7:00 pm Awards



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# DESIGN DAY 2019 KEYNOTE

## **MEDICAL ENTREPRENEURSHIP: WHY AND HOW**



#### Amarpreet Sawhney, PhD

Founder & Executive Chairman Ocular Therapeutix, Inc.

Dr. Amarpreet Sawhney is one of the most accomplished medtech innovators of his generation. Dr. Sawhney's roles include Founder, President and/or Chairman of Instylla, Ocular Therapeutix, Augmenix, Confluent Surgical, Focal, and Access Closure. His ideas are the subject of more than 120 issued and pending patents, including novel surgical sealants and spacers approved by the FDA: ReSure Sealant for ophthalmology, DuraSeal for neurosurgery, FocalSeal for lung surgery, Mynx for femoral puncture sealing, and SpaceOAR for prostate cancer radiotherapy.

Dr. Sawhney received a PhD in Chemical Engineering from UT-Austin and a BTech in Chemical Engineering from IIT-Dehli. Still starting and leading companies today, Dr. Sawhney's companies have created more than 2,000 jobs, and his inventions have improved the lives of more than five million patients.

# 2019 CLINICIAN INNOVATOR-MENTOR OF THE YEAR AWARD



#### Edward James Wright, III, MD

Director, Division of Reconstructive and Neurological Urology Johns Hopkins University School of Medicine and Bayview Medical Center

Johns Hopkins Medicine physicians are world leaders in the practice of medical care, committed to the institute's vision of "expanding the boundaries of discovery, transforming healthcare, advancing medical education, and creating hope for humanity."

Each year, many JHM physicians demonstrate this commitment by devoting their time, talent and creativity to mentoring teams of engineering students in the creation and implementation of innovative healthcare solutions. Through these collaborations, these physicians exemplify the Johns Hopkins "One University" mission--bringing together scientists, engineers, and clinicians to solve healthcare challenges through interdisciplinary scholarship and research.

To recognize these unique contributions, the Johns Hopkins Center for Bioengineering Innovation & Design established the Johns Hopkins Clinician Innovator-Mentor Award. This year, we are recognizing Dr. Edward James Wright, III, for his passion and dedication to improving patient lives through medical device innovation in collaboration with engineers.

Dr. Jamie Wright has more than 20 years of experience exploring the anatomy of the urogenital tract in men, women, and animal models small and large. His primary clinical and research interests and contributions are focused on complex pelvic reconstructive surgery in men and women, male and female urinary incontinence, complex voiding dysfunction, and urethral stricture disease. A highly skilled surgeon, he has a passion for teaching and mentoring, all in the goal of achieving better outcomes for patients.

This passion was made evident when he became a clinical mentor to a team of BME CBID master's students pursuing a project in the urethral stricture space. Dr. Wright committed his time with great enthusiasm, meeting frequently with the students to answer questions and collaborate on all phases of the innovation process. He became the first CBID mentor to participate in the National Science Foundation I-Corps program with the team of students staying on to transition the project into a product with commercial merit. Dr. Wright actively contributed to the development and testing of novel surgical methods and prototypes in the cadaver and large animal models needed to assess the potential of the team's concepts. Under his mentorship, the project secured seven grants and philanthropic donations, raising more than one million dollars.

This award is a token of heartfelt appreciation from all of the students and faculty here. Thank you!

## **POSTER SESSION PARTICIPANTS**

#### Undergraduate Design Team Program

- SymMEDtry: Minimizing Limb Length Discrepancy in Total Hip Arthroplasty Procedures
- MonitOR: Monitoring Instrument Flow in the Operating Room
- Benegraft
- Talaris Health: Chronic Care Management for Hydrocephalus Patients Using Inertial Measurement Analytics
- FlowMate: Ensuring Pediatric Patients Receive their Prescribed Dosage of Asthma Medication
- epiX: Novel Epidural Needle Design
- ObstetriCare: Obstetric Fistula Management in Low-Resource Settings
- Protek+: A Potassium Measuring Device to Prevent Cardiac Death in Dialysis Patients
- PediaCORE: Interactive Rehabilitation for Young Children with Cerebral Palsy
- Endosight: An Imaging Tool to Aid Surgical Trainees with Performing Colonoscopies
- Breast Cancer Biopsy in Low-Resource Settings
- EchO<sub>2</sub>: Post-Surgery Perfusion Monitoring
- CottInSight: Minimizing Unintended Cotton Retention in Neurosurgery
- Sapana Health: Screening for Obstructive Sleep Apnea

#### **MSE Design Program**

- Improving Central Venous Catheter Maintenance in the Home Setting
- TB-D: Improving Differential Diagnosis for Childhood Tuberculosis
- ForSight Innovation: Enabling Equitable Outcomes in Cataract Surgery
- DelTect: Predicting Postoperative
  Delirium in the ICU
- OxyGen: Portable Oxygen Supplementation
- Bronchoscopic Interventions for Emphysema
- NeMo: Empowering Mothers for Early Detection of Neonatal Illness
- Minimally Invasive Dynamic Stabilization of Lumbar Facets for Reduction in Low Back Pain

#### **Rehabilitation Engineering**

- WearyWatch
- Improving Hand Function in Osteoarthritis Patients
- ArmGaze
- An At-Home Stroke Rehabilitation Tracker for Upper-Limb Function and Interjoint Coordination

#### **Precision Care Medicine**

- A Pulse Arrival Time Based Method to Establish Blood Pressure Limits of Autoregulation and Optimal Blood Pressure in Individual Patients During Surgery
- Analytics of Prediction for Insomnia and Cognitive Impairment
- Physiologic Responses to Red Blood Cell Transfusion in Critically-III Pediatric Patients at a University PICU between 2014-2015
- Quantitative Assessment of TMJD-Induced Sleep Disorders and Prediction of Therapy Effectiveness
- Using Machine Learning Models to Predict the Likelihood of Patient Readmission to ICU
- Machine Learning-Based Prediction of Cardiac Arrest Outcome Using a Large Multi-Center Database

#### **Independent Design**

- An Apparatus for Precise Data Collection from Stroke Patients
- Redesigning Scrambler Therapy: A Neuropathic Pain Treatment Device
- Redesign of the Orthopedic Walking (CAM) Boot
- A BioMEMS Sensor for Monitoring and Controlling Biological Fluid Flow
- Oravi: Immersive Virtual Environments for Language Learning

#### **Advanced Design**

- Relavo: Reducing the Incidence of Peritonitis in Peritoneal Dialysis
- Quantishunt: Identifying Malfunction in Cerebroventricular Shunts
- Osteocast: Improving Distal Radius
  Fracture Management



## SymMEDtry: Minimizing Limb Length Discrepancy in Total Hip Arthroplasty Procedures

Team Members: Akash Chaurasia, Claire State, Katie McCarren, Jerry Yan, Evan Bender, Aditi Jithendra, Hannah Takasuka, Robert Li

Advisors: Julius Oni, MD; Amir Manbachi, PhD; Adam Levin, MD; Robert Sterling, MD; Jeff Siewerdsen, PhD; Megan Callanan; Tom Benassi; Matthew Hill

Abstract: Over 300,000 total hip replacements, also called total hip arthroplasties (THAs), are performed annually; this number is expected to rise to over 500,000 by the year 2030. In as many as 30% of these procedures, a limb length discrepancy (LLD) is introduced to patients, which occurs when one leg is longer or shorter than the other. Small LLDs (under a centimeter) can be corrected by shoe inserts and/or physical therapy, but significant LLDs (over 1.5 cm) require revision procedures to mitigate negative side effects, which can include an abnormal gait, hip instability, and joint pain. Over 30,000 THA revision procedures are completed each year due to LLD which equates to up to \$360,000,000 in extra healthcare expenditures annually. There are no current solutions which adequately address LLD during a THA procedure, leaving the majority of surgeons to check based on feel or sight alone. Orthopedic surgeons need a better method to minimize limb length discrepancy for patients undergoing total hip arthroplasty in order to reduce postoperative gait complications and revision procedures. SymMEDtry is working to develop a device that uses modern motion sensing technology to determine the distance between 3D registered points on the pelvis and femur. These 3D points will be analyzed by software that can determine the leg length discrepancy at any moment during the hip replacement procedure. Surgeons can then adjust the size of implants as necessary to reduce the LLD



### **MonitOR: Monitoring Instrument Flow in the Operating Room**

**Team Members:** Brett Wolfinger, Adit Murali, Kat Mayer, Anil Palepu, Lexie Scholtz, Cassie Parent, Christine Ji, Jacob Feitelberg

**Advisors:** Elizabeth Logsdon, PhD; Kofi Boahene, MD; Ryan Collar, MD, MBA; Nicholas Calotta, MD; Devin O'Brien-Coon, MD, MSE; Jerry Prince, PhD; Dan Greenberg, MBA, MS, CMRP; Sonavex--David Narrow, MSE; Michelle Zwernemann, MSE

**Abstract:** During an operation, the surgical team must keep track of the number of items used during the procedure to ensure that none are unintentionally retained inside the patient once the procedure is finished. In an estimated 81% of cases where a retained surgical item (RSI) is discovered, the manual count is thought to be correct. The count itself happens at the beginning of a procedure and is commonly documented on a whiteboard for reference. Recounts are performed throughout the procedure, most notably during changes of shift as well as at the end of the operation. If at any point the count does not match the reference established at the beginning, OR staff must stop the surgery to locate the missing instrument. If a change in staff occurs between a miscount and the last correct count, relieved staff members are contacted about the status of previously counted instruments, sometimes several hours later, thus requiring them to remain on call for the duration of the case.

MonitOR is a team of Johns Hopkins engineering students building a computer vision based system to tackle the problem of RSIs. Our system synthesizes data from cameras mounted throughout the operating room to provide a live snapshot of instruments in and around the patient. Additionally, our system will collect data on instrument usage and flow that can be leveraged to cut costs incurred further downstream.



#### Benegraft

Team Members: Sabin Karki, Brooke Stephanian, Allison Rosen, Paarth Sharma, Kirby Leo, Marc Di Meo, Mitsuki Ota, Millan Patel

Advisors: Patrick Byrne, MD, MBA; Wei-Ping Andrew Lee, MD; Chad Schneider, PE; Bhavana Mohanraj, PhD; Nicholas Durr, PhD

Abstract: Rhinoplasties are procedures in which plastic surgeons augment or reduce structures of the nose to resolve functional and aesthetic issues. Over 200,000 rhinoplasties are performed in the US annually, with a majority requiring the use of cartilage grafts. These grafts are typically harvested from the patient or a cadaver and provide structure or contour to the nose. Prior to implantation, grafts are shaped by the surgeon into the desired form by carving, crushing, or dicing the tissue. Dicing is the superior technique for developing contour grafts as it results in the fewest postoperative surgical complications, with revision rates estimated at 5% compared to 20% overall for the procedure. Despite its clinical benefits, surgical adoption of dicing methods is low due to the laborious and time-intensive process of manually dicing cartilage with a scalpel to the desired size (1 mm). As evidenced in surgeon feedback, the time required to dice cartilage is the primary factor discouraging surgeon use, taking up to 2 hours depending on the volume of cartilage necessary. Surgeons face issues with the cartilage sticking to the blade and their gloves, and difficulty cutting small pieces of hard cartilage. Thus, there is a need for a simplified surgical workflow for dicing cartilage in rhinoplasties. Benegraft is developing a novel device which can rapidly process cartilage, saving time in the OR and encouraging adoption of the dicing technique to improve patient outcomes.



## Talaris Health: Chronic Care Management for Hydrocephalus Patients Using Inertial Measurement Analytics

**Team Members:** Burton Ye, Mario Antoun, Taha Baig, Seyvonne Ip, Debanik Purkayastha, Autumn Hughes, Brandon Wong, Arjun Somayazulu

Advisors: Abhay Moghekar, MBBS; Youseph Yazdi, PhD, MBA

**Abstract:** Hydrocephalus, a neurological condition that affects approximately 700,000 Americans over the age of 60, results from cerebrospinal fluid (CSF) build-up in the brain ventricles. The current standard of care is implantation of a shunt in the brain, where a tube is inserted to drain CSF from the ventricles. However, these shunts malfunction in 32 percent of adult cases, which primarily manifests itself in gait disturbances. An unnoticed malfunctioning shunt may lead to brain damage, falls, and reduced lifespan. Regular checkups allow physicians to assess patients on gait parameters such as speed, endurance and balance and detect early warning signs of treatment failure. However, hydrocephalus patients often go several months to a year without check-ups - these patients would ideally be checked in on a more consistent manner. Due to limitations in resources, frequent in-person check-ups are not feasible. Our platform seeks to facilitate remote care management, allowing for continual interaction between the patient and physicians outside the clinic. The patient-facing mobile application processes data from built-in sensors regarding the phone's orientation, acceleration, and rotation rate. Patients complete the same gait assessments performed in clinic, and our algorithms extract clinically relevant features from the data provided by the phone's built-in sensors. Physicians are able to access a web-dashboard that provides HIPAA-secure patient data reporting and visualization, including longitudinal views of patient performance. From this, physicians will be able to recognize early warning signs of issues, and, in conjunction with their own analysis, make more informed decisions regarding patient treatments.



## FlowMate: Ensuring Pediatric Patients Receive their Prescribed Dosage of Asthma Medication

**Team Members:** Celine Arpornsuksant, Yunonne Bai, Damali Egyen-Davis, Varun Kedia, Colin Lee, Isaree Pitaktong, Max Xu, Lily Zhu

Advisors: Amir Manbachi, PhD; Carlton Lee, PharmD; Mandeep Jassal, MD, MPH; George Coles; Beth Laube, PhD

**Abstract:** Asthma is a chronic inflammatory disease affecting 25 million Americans, including seven million children. Current treatments include anti-inflammatory drugs delivered directly to the lungs, mainly through inhalers. There is a relatively novel type of inhaler called a dry powder inhaler (DPI) that dispels dry powdered medication upon inhalation. However, a staggering 32% of four- to nine-year-olds are unable to generate the 60 L/min required to receive adequate dosage of medication when using a DPI. Thus, a method of ensuring consistent and adequate drug deposition in the lungs from DPIs is needed in order to reduce chronic asthma symptoms in children. In order to bypass the need for patient-generated inspiratory flow in standard DPIs, active DPIs have been developed. These active devices use an energy source external to the patient to create aerosol dispersion and dislodge the drug from the powder bed or canister. However, these products have all been unsuccessful due to their complexity, high expense, and vulnerability to failure due to their dependence on outside energy sources and user-unfriendly designs. We have designed an attachable adaptor that will allow patients to reach the sufficient inspiratory flow to dislodge the medication from the inhaler and into their lungs. We hope that our device will help children alleviate their asthma symptoms.





Dry powder inhaler

#### epiX: Novel Epidural Needle Design

Team Members: Gabriel Fernandes, Amanda Li, Asef Islam, Diego Arevalo, Eshan Joshi, Chenyi "Lisa" Zhu, Matthew Zhao, Ernesto Lozano

**Advisors:** Asad Latif, MD, MBBS, MPH; Adam Sapirstein, MD; Youseph Yazdi, PhD, MBA; Andrew Malinow, MD; Becton Dickinson— Erik Witt, MD, PhD; Jude Cancellieri, MSE, MBA; Martin Jacobsen, MSc; Meghan Vellotti, MSE

Abstract: The standard length of epidural needles, three-and-a-half inches, is suitable for patients with a normal body mass index (BMI). However, these standard needle lengths are not compatible with obese patients. Studies indicate that 50% of the American population is obese or extremely obese, with obesity rates still on the rise. During an epidural anesthesia procedure, obese patients require longer needles to penetrate deeper layers of subcutaneous tissue separating the targeted epidural space and the skin. Either prior to or mid-procedure, a physician may decide that the three-and-a-half inch needle is too short for the patient. Then, a longer needle must be retrieved, introducing another object to the sterile field, and imposing an inconvenient and time-consuming process on both the practitioner and patient. Unfortunately, most hospitals have a limited supply of longer needles, necessitating an additional healthcare practitioner who presses down on the patient's back to decrease the distance to the epidural space during the procedure. Therefore, there is a need for a solution that minimizes procedure difficulty, decreases patient discomfort, and mitigates risk of infection. The goal of the project is to provide physicians with the ability to maintain optimal length needle to reach the epidural space, independent of patient BMI.



#### ObstetriCare: Obstetric Fistula Management in Low-Resource Settings

**Team Members:** Jacqueline Lanzaro, Emily Chang, Erika Bhadra, Siddharth Arun, Valerie Zawicki, Kevin Gorman, Helen Rossmiller, Pranavi Pallinti

Advisors: Elizabeth Logsdon, PhD; Chi Chiung Grace Chen, MD, MHS; Laura Keyser, DPT, MPH; Namratha Potharaj; Tom Benassi; Soumyadipta Acharya, MD, MSE, PhD; Bailey Surtees

Abstract: Over two million women in Sub-Saharan Africa and Asia suffer from the debilitating effects of an obstetric fistula. This abnormal hole that develops between the genital and urinary tracts is the result of prolonged. obstructed labor with the absence of timely effective medical care. The primary symptom of an obstetric fistula is the constant leakage of urine from the vaginal canal. While urinary incontinence has many physical effects such as odor, skin irritation, infection, secondary infertility, and even nerve damage, this condition extends far beyond physical effects. These women are unable to perform daily life tasks, are ostracized by their families and society, and often have increased rates of depression and even suicide. Within recent years, obstetric fistulas have become a focus point of global health efforts, revolving around three major themes: prevention, treatment, and management of symptoms. Most organizations are currently focused solely on the front end, dedicating time and money in efforts to raise awareness, educate populations, and collect funds for surgical treatment. However, while these organizations attack the problem from the source, they fail to address the lasting physical, social, and mental effects of an obstetric fistula. Simply closing the hole is not enough. Our team, following an insight informed innovation model, is designing a solution with a specific need in mind: Women with obstetric fistulas in lowresource settings need a method to minimize uncontrolled urine flow to

alleviate social distress caused by physical symptoms. While we hope that we can live in a world one day where obstetric fistulas no longer exist, for now we are dedicated to easing the burden of this devastating condition.



# Protek+: A Potassium Measuring Device to Prevent Cardiac Death in Dialysis Patients

**Team Members:** Parth Vora, Miguel Inserni, Min Jae Kim, Alan Lai, Maya Lapinski, Diane Lee, Justin Wang, Rebecca Yu

**Advisors:** Mohamed Atta, MD, MPH; Amir Manbachi, PhD; William Clarke, PhD; Dorene Holcombe, CRNP; Netz Arroyo, PhD; Collin Shale; Tom Benassi

Abstract: Of the 15.2% of Americans with chronic kidney disease (CKD), over 700,000 have kidneys that have deteriorated to the point where they are unable to filter out wastes and ions from the blood. These substances can then accumulate within the bloodstream and become toxic to the patient. Hyperkalemia, or excess levels of potassium, is a particularly deadly condition that CKD patients are at risk for. Potassium is critical in the functioning of the heart, so hyperkalemia places dialysis patients at a high risk for serious conditions such as sudden cardiac arrest and death. Hence these patients are placed on a dialysis schedule that runs three times a week to minimize the chance of these adverse outcomes. However, every week there exists a two day period where individuals will go without treatment. During this gap of treatment, studies have found a significant increase in cardiac-related deaths, of which 42% of the deaths of dialysis patients are classified to be cardiovascular in origin, likely the result of overlooking hyperkalemia due to its silent symptoms. This problem is compounded as dialysis patients have no good way to determine their risk of hyperkalemia at home. This leads to patient deaths due to cardiac complications that can easily be prevented by patient awareness of their blood potassium. To overcome these obstacles, our team is building a portable, point of care blood potassium measurement device to allow patients to accurately assess their risk of hyperkalemia related complications.





Figure 1. Protect + Polansovie Maniter

# PediaCORE: Interactive Rehabilitation for Young Children with Cerebral Palsy

**Team Members:** Samiksha Ramesh, Akaash Sanyal, Nicholas Maritato, Tatiana Gelaf Romer, Teya Bergamaschi, Joshua Park, Maggie Li, Sundari Parise

Advisors: Amy Bastian, PhD, PT; Elizabeth Logsdon, PhD; Keith Slifer, PhD; Deanna Johnson, PT; Cari Sullivan, PT, DPT

**Abstract:** For the 400,000 children in the United States suffering from cerebral palsy (CP), everyday activities requiring physical mobility can be a significant challenge. Underdeveloped and uncoordinated muscles lead to impaired trunk stability, often preventing development of the ability to independently sit up, reach for objects, and stabilize movements. The best treatment option to build trunk strength is physical therapy (PT). However, PT can be expensive, time-consuming, and/or geographically inaccessible. More accessible treatment options often provide only physical support and fail to help children develop the muscles they need to function independently. There is a clear need for a readily available, affordable, and enjoyable treatment option for children with CP in order to promote early rehabilitation and long-term improvement of motor function.

We present an at-home, interactive physiotherapy play center tailored specifically to meet the needs of two- to five-year-old children with CP. The play center, modeled after infant toy activity centers already familiar to parents, is highly customizable and provides support specifically suited to the needs of children with CP. It encourages children to stretch and reach in ways that mimic common physical therapy exercises, allowing them to build the trunk musculature necessary to gain independence. We aim for our low-cost solution to serve as a supplement to children who are already engaging in PT and as a partial treatment option for those families with no access to PT.





# Endosight: An Imaging Tool to Aid Surgical Trainees with Performing Colonoscopies

**Team Members:** Sanjay Elangovan, Justin Yan, Kamran Siddiq, Simon Liu, Amrita Ladwa, Eashwar Mahadevan, Roshini Narayanan, Adam Kenet

Advisors: Kenneth Ng, DO; Amir Manbachi, PhD; Jessica Dakkak; Tom Benassi; James West; Tossapol Kerdsirichairat; Catiele Antunes; Alexandra Strauss; Lance Lasner

**Abstract:** Colonoscopies are routine, low-risk procedures that are used to screen patients for diseases like colorectal cancer. However, in low cost and low resource settings, they are often times performed without sedation which results in pain and complications for patients. Without sedation, these procedures can be very painful, with one study reporting that more than 20% of patients experienced severe pain. This pain is often the result of a phenomenon called "endoscopic looping," which occurs when the scope loops within the patient's bowels and stretches out their intestines. Looping is extremely common, and occurs in up to 90% of procedures. Endosight is a low cost endoscopy visualization device used to decrease patient pain during colonoscopies and time lost due to complications experienced during procedures. The device consists of a piezoelectric rod and external console, giving physicians a real time view of the colonoscope during procedures.



Source for illustration: https://newsnetwork. mayoclinic.org/discussion/mayo-clinic-q-and-a-painmanagement-during-colonoscopy/

#### **Breast Cancer Biopsy in Low-Resource Settings**

**Team Members:** Sondra Rahmeh, Sachin Aggarwal, Pamela Chansky, Julia Costacurta, Nick Garza, Trifeena James, Marissa McDonald, Nela Mohan

Advisors: Susan Harvey, MD; Elizabeth Logsdon, PhD; George Coles, MS; Bailey Surtees, BS; Su Lucas, MBBCh; Soumyadipta Acharya, MD, MSE, PhD; Alexandra Berges, BS; Adam Dodson, NRP

**Abstract:** The incidence of breast cancer in South Africa is approximately 35 per 100,000 people, with a five-year survival rate of about 50%, compared to 90% in the United States. This disparity in care demonstrates the need for change in breast cancer treatment in South Africa. While the primary care setting is easily accessible and equipped with the necessary biopsy tools, providers often do not have the degree of user skill necessary to manipulate the ultrasound transducer and biopsy device to maintain clear visualization of the needle on ultrasound imaging. Poor needle visualization can lead to incorrect needle placement, negatively impacting the retrieval of a tissue sample and putting the patient's safety at risk. Secondary and tertiary healthcare facilities are more capable of performing biopsies; however they are more difficult to access due to challenges including time, cost of transportation and lodging, and increased dependence on family or community members. As a result, women receive a delayed diagnosis or do not get a diagnosis, falling out of the continuum of care. Our team has developed a device that supports the ultrasound transducer while allowing the user to maintain clear needle visualization in plane with the transducer, thereby reducing the burden on the user to coordinate multiple devices and navigate the biopsy needle through the patient's breast. In effect, the provider is free to use both hands to operate the biopsy device and focus on directing the needle to the lesion for a safe and effective procedure in a primary care setting. Our solution brings safe biopsy to local clinics, which are often the



closest point of access for rural women, thereby decreasing the time, distance, and cost factors that limit these women from obtaining a necessary breast biopsy.



Left: A lask view of the solution used for a biago of a breast lesion (red). The ultrasound transducer fits rest the transits (down) for handly free usages. The transfer run a const the thermain (for the vitasioned transducer to be able to move across the surface of the breast. Arghet: A forst view of the breast. There is agen space around the transfer for instruction of the baroost Arghet. A forst view of the breast. There is agen space

## **EchO<sub>2</sub>: Post-Surgery Perfusion Monitoring**

**Team Members:** Santiago Balza, Gabrielle Grifno, Disha Mishra, Yujin Park, Shihab Rahman, Victor Wang, Lucy Wu, Jack Yue

**Advisors:** Nicholas Durr, PhD; Keith Aziz, MD; Jason Hammond, MD; David Weiner, MD; Carter Freiburg, MD; Anthony Ho, BS

**Abstract:** Peripheral arterial disease (PAD) is a condition which results in reduced blood perfusion (blood flow) to the legs. 600,000 PAD patients require revascularization surgery annually and are monitored post-surgery for poor perfusion, which indicates surgical complications. Without timely detection of these complications, consequent widespread tissue death in the legs can lead to amputation. Current technologies used to monitor perfusion post-surgery are heavily skill dependent, costly, or have long wait times, and thus often fail to alert clinicians to insufficient perfusion in a timely manner. If the early onset of low blood perfusion can be easily, inexpensively and reliably detected, vascular surgeons would be able to successfully re-intervene and correct surgical complications for more patients, thus avoiding amputation of a limb that can no longer be salvaged.

Our solution to fill this need for a reliable, accessible tool for perfusion monitoring is EchO<sub>2</sub>, a handheld device that uses cloud computing to measure perfusion from captured video of a patient's skin. The device has a screen that displays a dynamic visualization of perfusion which allows clinicians to quickly and easily identify areas that have insufficient blood flow without additional specialized training. Furthermore, EchO<sub>2</sub>'s minimal output wait time allows clinicians access to a high throughput system: more patients can be monitored with higher frequency than the current standard, drastically reducing the chances that a patient's condition will critically decline without being detected.



# CottInSight: Minimizing Unintended Cotton Retention in Neurosurgery

**Team Members:** Raphael Bechtold, Zachary Buono, Isabella Ferrara, Benjamin Garlow, Sean Glaister, Cristina Madalo, Jimmy Pitingolo, Niki Tselepidakis

**Advisors:** Judy Huang, MD; Amir Manbachi, PhD; Henry Brem, MD; George Coles; Ian Suk, BSc, BMC; Jennifer Elisseeff, PhD; Anping Xie, PhD; Noah Gorelick, PhD; Camilo Molina, MD; Tom Benassi; Collin Shale

Abstract: Neurosurgical operations are intensive medical procedures that often last several hours, during which the surgeon must be intensely focused to ensure a safe and successful outcome. Surgeons need to constantly have an unobscured view of the brain in order to be able to properly operate, and thus use a variety of tools to clear obstructions (like blood and fluid) from the operating area. Currently, cotton balls are the most versatile and effective option to accomplish this. They are able to absorb fluids, safely manipulate the brain, act as a barrier between other tools and the brain, and act as a spacer to keep areas of the brain open during the operation. While cotton balls allow neurosurgeons to effectively improve visibility of the operating area, they are also prone to being accidentally left in the brain upon completion of the surgery. This can cause a dangerous immune response in the patient, leading to discomfort, additional medical care or surgical operations, and potentially death. Our project seeks to develop a method to decrease the likelihood of these undesired post-operative risks by reducing the possibility of cotton balls being left in the brain, while still maintaining the ability to remove visually obstructive fluids from the operating area. We are currently pursuing the development of several methods to improve visualization of cotton in both the surface and interior environments of the brain, thereby decreasing the risk of unintended cotton retention after these operations.



### Sapana Health: Screening for Obstructive Sleep Apnea

Team Members: Zhou Li, Andrew Jin, Rohan Panaparambil, Kevin Zhan, Rupsa Acharya, Vani Kumar, Andrea Niu, Charles Wang

**Advisors:** Rachel Salas, MD; Charlene Gamaldo, MD; Nicholas Durr, PhD; Tami Whittman; Todd Murphy

**Abstract:** Obstructive sleep apnea (OSA), the intermittent cessation of breathing during sleep, affects roughly 22 million Americans. Untreated OSA is associated with serious comorbidities, including obesity, diabetes, stroke and heart disease. Despite its prevalence, as many as 80% of OSA cases remain undiagnosed. Because OSA indicators only manifest during sleep, many patients fail to notice symptoms and typically do not bring up concerns with their primary care physicians (PCPs). Even in patients who do express their concerns, inadequate consultation time and insufficient sleep health education among PCPs further exacerbates the issue of underdiagnosis. The current standard of screening is a questionnaire that requires patients to self-report on subjective metrics like quality of sleep; however, these questionnaires are unreliable because patients tend to overestimate quality and duration of sleep. Thus, health practitioners need an objective tool that can easily integrate into routine health checkups to screen patients for OSA. With that in mind, we created SomnoSnap, a handheld 3D-imaging screening

tool that assesses patients' likelihood of having OSA, and is intended for use during routine examinations at dental clinics. It uses structured light to generate a 3D scan of the patient's upper oral airway. The scan will be evaluated according to a classification scheme known as the Mallampati scoring criteria, which correlates with the likelihood of upper airway collapse and serves as a predictor for OSA. Our solution also allows patients to visualize their oral cavity and their risk for OSA, thus motivating them to seek further diagnosis and





treatment. By making SomnoSnap accessible at dental clinics, the diagnostic paradigm will shift from being patient-initiated to clinician-initiated, allowing the public to easily obtain sleep apnea screening.





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#### Improving Central Venous Catheter Maintenance in the Home Setting

**Team Members:** Matthew Hill, Bonolo Mathekga, Mete Morris, Melissa Schweizer, Collin Shale, Digvijay Singh

**Advisors:** MiKaela Olsen, MSN; Cliff Weiss, MD; David Hirsch, MSN; Swapna Kakani; Emily Levy; Yushi Yang, PhD; Trish Brown, LDN

**Sponsors:** Becton Dickinson Medical Delivery Solutions: Pratik Patel; Erik Witt, MD, PhD; Matthew Oshinski; Maarten Brand

**Abstract:** The use of central venous catheters (CVCs) is pivotal for the delivery of life-saving and life-sustaining medications to patients requiring high-flow therapies or vesicant drugs. As with any vascular access device, the same pathway that is used to deliver these therapies can also introduce pathogens into the bloodstream causing life-threatening infections.

While multiple standards and intervention bundles have been championed to reduce the incidence of these central line associated bloodstream infections (CLABSIs) in inpatient settings, little attention has been paid to the use of CVCs in home-based therapies. The resulting reality is that the 525,000 patients receiving outpatient parenteral antibiotic (OPAT) or home parenteral nutrition (HPN) therapies must perform central line maintenance, a task normally performed by trained medical professionals, by themselves with minimal training and education.

OPAT and HPN patients specifically are at risk for CLABSIs as they tend to have a longer indwelling time for their lines ranging from 20-300 days at a time. Our team is developing solutions to increase compliance with central line maintenance in the home setting by addressing the three major challenges faced by stakeholders: (1) Limited training received by patients prior to expectation to perform maintenance tasks normally done by a professional nurse, (2) inconsistent surveillance of patient central line maintenance compliance to identify and intervene with non-compliant patients before adverse events occur, and (3) Complex and non-standardized maintenance procedures that make it difficult for patients and caregivers to perform consistent and proper maintenance procedures. The team is developing solutions that are addressing these pertinent issues that home infusion patients face, with the goal of keeping discharged patients out of the hospital. There is an increasing push for infusion care to move toward the home setting, and we are designing our solution to improve patient outcomes in a rapidly growing space.

### TB-D: Improving Differential Diagnosis for Childhood Tuberculosis

Team Members: Matthew Hill, Bonolo Mathekga, Mete Morris, Melissa Schweizer, Collin Shale, Digvijay Singh

**Advisors:** Soumyadipta Acharya, MD, MSE, PhD; Sylvia Hinrichsen, MD, PhD; Jonathan Golub, PhD, MPH; Neil Martinson, MBBCH, DCH, MFGP, MPH; Gavin Churchyard, MBBCH, FCP (SA), MMed, PhD

**Abstract:** Each year, it is estimated that over one million children are infected with active tuberculosis (TB) resulting in over 233,000 deaths. Of these deaths, it is also estimated that 96% occur in children that were never treated for TB. Diagnostic testing used for adult tuberculosis has reduced sensitivity in children less than five years of age, and the clinical symptoms and signs of childhood TB overlap with many other childhood diseases. In Sub-Saharan Africa, this problem is further complicated by the current HIV epidemic as children with both HIV and TB are at risk of developing extrapulmonary TB. Childhood TB is specifically difficult to differentiate from other lower respiratory tract infections (LRTIs) in children with recent evidence indicating that childhood TB is especially missed in children presenting with symptoms of acute pneumonia.

TB-D is researching and developing a solution to assist healthcare providers in correctly differentiating childhood TB from other LRTIs. In the Sub-Saharan Africa context specifically, healthcare providers rely on patient history and clinical investigations in order to determine how likely a child is to have TB. Depending on the level of suspicion, healthcare providers will order diagnostic testing for children or even begin empirical treatment; however, when healthcare providers suspect a different LRTI, they may begin treatment for the wrong LRTI. This improper diagnosis leads to diagnostic delay for children with TB along with lost follow-up among children that seek alternate care sources. TB-D is developing a solution that will assist healthcare providers in correctly suspecting TB within children, resulting in increased detection and treatment of childhood TB.

Our team has conducted observations across multiple levels of care in South Africa in order to validate the need and assess current provider practices for investigating children with LRTIs. Healthcare providers across primary, outpatient, and inpatient care have confirmed the current difficulties with differentiating childhood TB from other LRTIs. Moving forward, the team will be focused on testing prototypes with users and validating the efficacy of our design in precisely identifying children with TB.

#### ForSight Innovation: Enabling Equitable Outcomes in Cataract Surgery

Team Members: Nick Calafat, Daniel Myers, Namratha Potharaj, Brittany Reed, Joshua de Souza, Krithik Srithar

**Advisors:** Soumyadipta Acharya, MSE, MD, PhD; Youseph Yazdi, PhD, MBA; Aditya Polsani, BDS, MS; Kunal Parikh, PhD; R.D. Ravindran, PhD; John Sheets, PhD; Martin Spencer, PhD; Thulasiraj Ravilla, MBA; Zervin Baam, PhD; Balaji Velayeutham, PhD; Samuel Yiu, MD, PhD; David Friedman, MD, PhD, MPH; Katie Solley

**Abstract:** Approximately 94 million people worldwide have impaired vision due to cataract, with a disproportionate number living in low- and middleincome countries (LMICs). Despite a continuous rise in cataract surgical rates, there remains a backlog of up to 16 million individuals awaiting surgery. To tackle the backlog of cataract surgeries, institutions like the Aravind Eye Care System in Madurai, India, provide high surgical throughput (>300 surgeries/ day) and subsidized care for patients of low socioeconomic status. Manual Small Incision Cataract Surgery (MSICS) has become the standard of care throughout LMICs and is a safe and effective surgery that meets the cost and time demands of a high-volume eye care center. In comparison to the goldstandard phacoemulsification (phaco) procedure, which is more widely used in developed countries, MSICS can be performed twice as fast and at a guarter of the cost. However, MSICS leads to significant rates of surgically induced astigmatism (SIA), resulting in impaired postoperative visual acuity. Additionally, MSICS patients require twice the time to recover after surgery in comparison to phaco patients. This results in a loss of income for patients who are often the sole breadwinners for their families

Through 100+ surgical observations and 35+ interviews with cataract surgeons at Aravind and the Johns Hopkins Wilmer Eye Institute, our team identified the primary root cause of poor MSICS patient outcomes to be the size of the surgical incision. While phaco uses ultrasonic energy to fragment and remove the cataract through a 2-3mm incision, MSICS requires a much larger 6-8mm incision to remove the cataract as a whole. Working side-by-side with experts at Aravind and Wilmer, our team has developed a surgical device capable extracting a cataract through a smaller incision while maintaining the time- and cost-efficiency of MSICS. Our solution translates the best qualities of phaco into a technology that is suitable for high-volume eyecare systems, thus enabling equitable patient outcomes independent of socioeconomic status.

### **DelTect: Predicting Postoperative Delirium in the ICU**

Team Members: Nick Calafat, Daniel Myers, Namratha Potharaj, Brittany Reed, Joshua de Souza, Krithik Srithar

**Advisors:** Soumyadipta Acharya, MSE, MD, PhD; Youseph Yazdi, PhD, MBA; Aditya Polsani, BDS, MS; Robert Stevens, MD, FCCM; David Giarracco, BS, MA; Michael Mestek, PhD; Cole Confer, MBA; Katie Solley



Sponsor: Medtronic Minimally Invasive Therapies

**Abstract:** Each year, up to 50% of the 16 million surgical patients who are at least 65 years of age develop postoperative delirium (POD) during their hospital stay. POD is a neurological condition that describes a change in the patient's mental status from their presurgical baseline that is independent of any preexisting neurocognitive disorder. It is characterized by inattention, disorientation, memory problems, disorganized thought, and perceptual disturbances. Multiple studies have associated POD with increased length of hospital stay, greater rates of institutional placement upon discharge, and long-term cognitive decline. Given that these effects are more pronounced with a longer duration of delirium, early and effective treatment is a high priority.

Despite the prevalence of POD and availability of screening tools, POD goes undiagnosed in up to 70% of all cases. Key stakeholder feedback suggests this widespread under-diagnosis is explained by the inadequacy and subjectivity of current behavioral screening tools. Nurses, who are the primary administrators of these screening tools, are often unable to identify subtle symptoms of delirium. Strong evidence shows that preventive interventions prior to clinical emergence of symptoms are highly effective in reducing the incidence and severity of delirium. However, there is wide under-implementation of preventive strategies due to a lack of monitoring solutions that can accurately predict the onset of delirium.

DelTect is a bedside monitor, used in the immediate postoperative space to assess a patient's risk for developing delirium. The team has developed a novel algorithm based on physiological precursors to predict delirium independent of clinically observable symptoms. DelTect will empower heavily burdened nurses to allocate resources and attention to high risk patients. By enabling better management of delirium, DelTect aims to reduce length of hospital stay, institutional placement, and long-term cognitive impairment.

#### **OxyGen: Portable Oxygen Supplementation**

**Team Members:** Ana Ainechi, Jessica Dakkak, Brice Dudley, Moriah Mattson, Jonathan Smith, Wilson Tang

**Advisors:** Sonye Danoff, MD, PhD; Stephen Mathai, MD, MHS; Meredith McCormack, MD, MHS; Soumyadipta Acharya, MSE, MD, PhD; Youseph Yazdi, PhD, MBA; Ashish Nimgaonkar, MD; Robert Storey; Lawrence Aronhime, MS, MBA; Laura Scavo, MS

**Abstract:** Approximately 2.1 million patients in the United States require portable oxygen therapy to treat their respiratory diseases. Patients choose from portable oxygen tanks that hold compressed gaseous O2 or portable oxygen concentrators (POCs) that concentrate oxygen from ambient air. While oxygen tanks are mobile and do not require batteries, they contain a finite amount of oxygen, are cumbersome, heavy, and difficult to maneuver. POCs are smaller, lighter, and the gold standard for portability; however, they have a limited battery life and can only provide support to patients requiring low amounts of oxygen (1-3L/min). This automatically disqualifies 20% of patients from using POCs due to their oxygen requirements.

The technological limitations of current offerings lead to reduced mobility, initiating a vicious cycle of social isolation, depression, and poor quality of life. As flow rates increase and mobility drops, patients rapidly progress towards becoming completely homebound. With the increasing prevalence of respiratory diseases and the clinical urgency for greater mobility, a longer lasting portable treatment is imperative.

We are developing a POC that uses respiratory support mechanisms developed for the intensive care unit to increase the efficiency and lifespan of portable oxygen devices. Our goal is to expand the technologies of current POCs beyond the 3L/min barrier to improve patient mobility and quality of life.

#### **Bronchoscopic Interventions for Emphysema**

**Team Members:** Ana Ainechi, Jessica Dakkak, Brice Dudley, Moriah Mattson, Jonathan Smith, Wilson Tang

**Advisors:** Hans Lee, MD; William Krimsky, MD; Soumyadipta Acharya, MSE, MD, PhD; Youseph Yazdi, PhD, MBA; Cliff Weiss, MD

**Sponsors:** Coridea/EOLO Medical: Howard Levin, MD; Mark Gelfand; Zoar Engelman, PhD; Anisha Bapna; Don Tanaka; Ary Chermorovsky; Angela Yang

**Abstract:** Emphysema is a lung disease caused by chronic inhalation of irritants and characterized by the destruction of alveolar walls, loss of tissue elasticity, abnormal and irreversible hyperinflation of the lung, and difficulty breathing. As a consequence of alveolar destruction and in addition to the loss of gas exchange, emphysematous regions of the lung trap air and expand, crowding out healthy portions of the lung and reducing the patient's overall expiratory capacity.

While there is no cure for emphysema, a class of minimally invasive therapies called bronchoscopic lung volume reduction (BLVR) is being developed. BLVR techniques are based on the proven theory that reducing the volume of the diseased portion of the lung will allow expansion and increased ventilation of the remaining healthy portions. Despite their promise, these therapies have found only moderate success in restoring respiratory capacity due to certain anatomical variations common in emphysema. These variations generate a phenomenon called collateral ventilation, which renders the best treatments ineffective for up to 75% of the more than 75 million emphysema patients worldwide.

Our team is working to develop multiple bronchoscopic interventions that mitigate the effects of collateral ventilation to expand the treatable population of emphysema patients.

#### NeMo: Empowering Mothers for Early Detection of Neonatal Illness

**Team Members:** Anthony Ho, Shababa Matin, Natalie Ng, Madison Vanosdoll, Allison Wallingford, Ryan Xu

Advisors: Soumyadipta Acharya, MSE, MD, PhD; Christopher Golden, MD; Alain Labrique, PhD; Peter Waiswa, MPH, PhD; Moses Kyangwa; Azadeh Farzin, MD

Abstract: Each year, 3.3 million newborns die in the first 28 days following birth, with 75% of these deaths occurring in the first seven days of life. A majority of these deaths occur within homes in low-resource settings, largely due to preventable causes such as pneumonia, sepsis, and other illnesses. Healthcare systems in low-resource settings often rely on volunteer community health workers (CHWs) to visit newborns in rural villages in the first week of life for triage. CHWs triage newborns based on the World Health Organization's established Integrated Management of Newborn and Childhood Illness (IMNCI) danger signs: difficulty breastfeeding, convulsions, chest indrawing, movement only when stimulated, respiratory rate greater than 60 breaths per minute, temperature higher than 37.5 °C, and temperature less than 35.5 °C. The number of CHWs, however, remains woefully inadequate and thus infants with signs of illness are often identified too late to impact survival. Although effective identification of these signs at the community level can intercept illness and incite care-seeking behavior capable of impacting child mortality, the tools and training needed to assess quantitative and gualitative indicators of illness are lacking in low-income settings.

Therefore, our team has developed the NeMo system, a two-part neonatal monitoring system designed to empower mothers, regardless of literacy, to effectively identify danger signs in their newborns and guide them to take appropriate and timely action to seek care outside the home. This system is comprised of a low-cost wearable band that measures the newborn's respiratory rate and temperature and is paired with a smartphone application that guides the mother through the qualitative danger signs. Our team has travelled to Uganda to validate the usability of this system and tailor-fitted the NeMo system to the end user. Currently, the NeMo system is undergoing validation testing in the Johns Hopkins Nursery where data collection enables breath-by-breath analysis to iteratively improve the respiratory rate algorithm's overall sensitivity and specificity. The team will return to Uganda to perform an acceptability study where mothers will be observed under the intended use case to study barriers of adoptions and behavior change triggered by the NeMo system.

# Minimally Invasive Dynamic Stabilization of Lumbar Facets for Reduction in Low Back Pain

**Team Members:** Anthony Ho, Shababa Matin, Natalie Ng, Madison Vanosdoll, Allison Wallingford, Ryan Xu

Advisors: Sheng-Fu Larry Lo, MD, MHS; Amit Jain, MD; Allan Belzberg, MD; Amanda Buxton, PhD; Matt Dreher, PhD; Clifford Weiss, MD

#### Sponsor: BTG

**Abstract:** At any given time, one in ten Americans suffer from lower back pain, and it is estimated that approximately 31% of this is attributed to the facet. The facet is a gliding synovial joint that works to limit motion and support the axial loads of the body. Patients typically experience facetmediated lumbar pain secondary to conditions such as age-related degeneration, trauma, or spinal deformities. Pathophysiologic changes accompanying degeneration of the facet joint can include the following: increased loading, wear of the cartilage surface, painful bone-on-bone contact, micromotion and prolonged inflammation.



Patients who exhaust conservative treatment can receive radiofrequency ablation (RFA) of the peripheral nerve to prevent transmission of pain signals. RFA, however, only provides relief for a limited duration and has decreased efficacy in repeat procedures. The only remaining option for patients is spinal fusion, an extremely invasive procedure that limits the normal motion of the body and has poor long-term outcomes. Therefore, patients experiencing facet-mediated pain need a minimally invasive treatment option to fill the therapeutic gap between non-operative treatments and invasive surgical intervention.

While other solutions exist to address this gap in care, all of these options are addressed towards surgeons who have little incentive to use these products over performing spinal fusion because open surgery is still required. Therefore, we have designed our solution to be targeted towards the skillsets of interventionalists. Our goal is to provide patients with longer and greater pain relief than the current standard without the need for invasive surgery.

To this end, our team has developed ZyGuard, a two-part system comprised of a catheter-based delivery system and an injectable implant. The flexible spacer works to prevent the painful bone-on-bone contact while maintaining a healthy range of motion of the facet. The delivery system enables interventionalists to access the degenerated facet, appropriately re-establish the intra-articular space, and deploy the injectable implant. Our team believes that this two-part ZyGuard system will revolutionize treatment of low back pain.

#### WearyWatch

Team Members: Najwa Faqih, Ananya Gupta, Shipra Khatri, Calvin Qian, Abhinav Harish

Advisors: Scott Paul, MD

Abstract: According to the CDC, every year, a total of five million people suffer from fibromyalgia in the United States alone. One of the most common symptoms of fibromyalgia is chronic fatigue. The impairments associated with fatigue are distinct from occasional tiredness. Fatigue is a multifactorial condition which requires the usage of subjective and objective measures for diagnosis and treatment. Symptoms of fatigue include unrelenting exhaustion, a constant state of weariness that develops over time, and a general reduction of energy, motivation, and concentration. This often leads to interference with activities of daily living. Current diagnostic methods for fatigue rely on patient recall surveys and thus, the diagnosis of fatigue relies heavily on subjective measures. Selective remembrance of recent fatigue and activity by patients can skew patients' reported fatigue levels, making subjective reports less reliable, and therefore it is important to incorporate objective measures in fatigue diagnosis. As a result, we have identified a need for a system to assess fatigue that accounts for continuous monitoring of both objective and subjective factors in order to better plan treatment for fatigue.

WearyWatch is a smart wristband device that incorporates continuous measurement of objective aspects of fatigue such as heart rate and activity, while simultaneously collecting patient-reported levels of fatigue. The device is conveniently located on the patient's wrist and will allow for easy real-time monitoring of fatigue. This data is then compiled and provided to clinicians in a simple graphical format that can be used for better fatigue assessment.

With the aid of WearyWatch, clinicians are able to track trends in patients' objective and subjective fatigue, allowing them to better assess chronic fatigue and provide better treatment plans for patients.

### **Improving Hand Function in Osteoarthritis Patients**

**Team Members:** Gabriel Anfinrud, Pamela Chansky, Matthew Fernandez, Cristina Madalo, Ryan Najmi

Advisors: Scott Paul, MD; Simon Orozco; Moriah Mattson

**Abstract:** In the US alone, approximately 23 million people suffer from hand osteoarthritis. This condition causes decreased strength, range of motion, and dexterity, in addition to joint inflammation and pain. These conditions and symptoms contribute to a decrease in hand function, which we define as the actions and operations of the fingers, joints, and muscles of the hand, both as a whole and as their individual parts. The most valuable aspect of joint mobility loss is related to the thumb, as thumb dexterity is what allows humans to grip effectively. Currently, treatment consists of both drug-based and physical therapies. Drug treatments only target symptoms, such as joint inflammation and pain. The existing physical therapy solutions are comprised of a combination of resistance and intensity exercises as well as splinting. None of the existing physical therapy solutions target thumb strength and effectively engage the patient population or track the user's progress. Our solution engages users in an isometric thumb exercise through a device that measures their applied force and provides feedback to the user and data to the clinician. This solution would allow a larger fraction of the target population to engage in less invasive treatments and improve their hand function.



#### ArmGaze

**Team Members:** Alina Andrews, Nicholas Hou, Jimmy Li, Momin Mohis, Shayan Roychoudhury

Advisors: Scott Paul, MD; Simon Peter Orozco

Abstract: Persons with cerebral palsy (CP) have motor dysfunction occurring in both lower and upper limbs. Hemiparetic CP affects one side of the body, and is typically associated with significant impairments in the coordination of upper limb function. Clinicians evaluate severity of upper-limb impairment via a series of tests, monitoring children's ability to complete functional tasks. Often times, the completion of these tasks is reliant on abnormal compensatory movements, such as at the trunk and shoulder. This is common in activities requiring supination of the wrist. Use of compensatory movement patterns can result in weaker muscles in the affected area which, in turn, can create further unwanted compensations. We have developed a tool for measuring level of compensation during therapy to assist clinicians in developing and monitoring their rehabilitation treatment programs. Our device incorporates accelerometers at the shoulder, elbow, and wrist to provide quantitative information to the therapist on the movement pattern and how it deviates from the desired pattern.



## An At-Home Stroke Rehabilitation Tracker for Upper-Limb Function and Interjoint Coordination

**Team Members:** William Kim, Ben Lee, Jessica Liu, Nicholas Radant, Bengu Ulukaya

Advisors: Scott Paul, MD; Jessica Dakkak; Simon Orozco

Abstract: Stroke is the fourth leading cause of disability worldwide, and it is therefore a global health problem. In developed countries, stroke is the leading cause of disability and the second leading cause of death. The disease occurs when blood supply to part of the brain is blocked or when a blood vessel in the brain bursts. About 85% of stroke survivors experience some degree of paresis of the upper limb, and about 50% of the survivors show impaired upper limb and hand function in the chronic phase. Because such a high proportion of stroke patients experience some degree of upper limb impairment, measurement of upper limb function is paramount for diagnosis of symptoms and evaluating efficacy of rehabilitation interventions. However, assessment of stroke rehabilitation is unfortunately lacking in the clinic. Despite the availability of comprehensive tests of upper limb function like the Fugl-Meyer Test, these tests are not frequently used in weekly clinic visits due to time constraints and burden on the patient. As a result, clinicians often favor faster and simpler tests like the Nine Hole Peg Test, which are limited in their assessments of upper limb function. Thus, there is potential in developing assessments for the home environment to reduce patient burden and time spent in clinic while still producing comprehensive data about patient recovery. The intention of this project is to develop such an assessment platform for at-home assessment of upper limb stroke rehabilitation.

## A Pulse Arrival Time Based Method to Establish Blood Pressure Limits of Autoregulation and Optimal Blood Pressure in Individual Patients During Surgery

**Team Members:** Yuchen Ge, Shiyu Luo, Bonolo Mathekga, Yinuo Zeng, Shichen Zhang

Advisors: Viachaslau Barodka, MD; Dan Berkowitz; Charlie Brown, MD; Joseph Greenstein, PhD; Raimond Winslow, PhD

**Abstract:** The regulation of blood flow into peripheral organ systems is imperative to maintain adequate perfusion and prevent tissue damage. The human body accomplishes this task through autoregulation, a mechanism which maintains relatively constant cerebral blood flow despite changes in blood pressure. Autoregulation, however, works only within a limited range of blood pressures and fails to ensure constant cerebral blood flow outside of this range. Under current standards, cerebral oximetry has been used as a surrogate for cerebral blood flow in non-invasive multimodal monitoring of the cerebral autoregulation. However, this method is expensive and thus not widely used in the operating room and intensive care unit (ICU).

In this project, we propose a novel method using real-time continuous electrocardiography and arterial blood pressure data to establish the limits of autoregulation and establish the optimal blood pressure for individual patients in the operating room and ICU. Our method uses a combination of pulse arrival time (PAT), the time it takes the pulse to reach the end organ, and the mean arterial pressure (MAP) to derive the individualized autoregulation limits. Based on the observation that the variance of PAT differs within and outside of the autoregulation limits, the Brown–Forsythe test for constancy of variance is applied between sliding windows across MAP and an adaptive control window, in order to draw the boundaries for the lower and upper limits of autoregulation. Using this method, we were able to determine the autoregulation limits of 100 patients. Future work should include evaluating the performance of our technique against the results of the cerebral oximetry based method.



#### **Analytics of Prediction for Insomnia and Cognitive Impairment**

**Team Members:** Ali Al Abdullatif, Amy He, Elysia Chou, John Lin, Jung Min Lee

Advisors: Sridevi Sarma, PhD; Charlene Gamaldo, MD; Rachel Salas, MD; Alyssa Gamaldo, PhD

**Abstract:** Insomnia is the most common sleep disorder in the United States and affects approximately 60 million Americans. Patients with insomnia also have an increased risk for cognitive impairment. However, insomnia and cognitive impairment are currently diagnosed through subjective clinical interviews with sleep experts and self-reported screening tools. The goal of this study is to create an objective computational model that can predict insomnia and cognitive impairment from physiological recordings obtained during sleep. We construct and test our model using data collected from either polysomnography that was conducted in a sleep center or an ambulatory Sleep Profiler<sup>™</sup> device that can be worn at home. Our cohort consists of HIV seropositive patients (n = 31) who are known to suffer from both insomnia and cognitive impairment. Physiological signals from these patients can be used to derive hundreds of sleep stage-specific features, such as average power of a given frequency band from a specific brain area. Generalized Linear Models (GLMs) are then utilized to select the most predictive features for insomnia and cognitive impairment. If successful, our model can provide an accessible and objective means of diagnosing insomnia and identifying patients with cognitive impairment for cognitive behavioral therapy.



#### Physiologic Responses to Red Blood Cell Transfusion in Critically-III Pediatric Patients at a University PICU between 2014-2015

Team Members: Michiru Fredricks, Andrew Jin, Gaurav Sharma, Jasen Zhang, Roger S. Zou

Advisors: Sridevi Sarma, PhD; Melania Bembea, MD, MPH, PhD



Abstract: In critical care units across

the world blood transfusion decisions currently rely heavily on a patient's hemoglobin concentration, though there is a consensus that clinical judgment also plays an important role. There is a lack of quantitative data to drive these clinical judgements, causing them to be based more on clinician's experience than insights from the data. Furthermore, for patients in the Pediatric Intensive Care Unit (PICU), characterization of correlations between the decision to transfuse and effects on physiologic variables and clinically significant outcomes require further investigation.

Our objective is to identify key physiological features that significantly change after transfusion in PICU patients, to ultimately model these changes, and to predict adverse outcomes in order to provide clinicians with more data-driven insights to aid transfusion decisions. In order to accomplish this, we present a 15-month retrospective electronic health record cohort study. We obtained time series data from 2156 pediatric patients admitted to the Johns Hopkins Hospital PICU from July 2014 to October 2015. To remove confounding effects from previous procedures, only the first transfusions in their first PICU visit were analyzed. Preliminary variables investigated include median heart rate (HR), respiratory rate (RR), and peripheral capillary oxygen saturation (SpO2). Transfusions were categorized based on the patient's pre-transfusion hemoglobin levels in the clinically relevant categories: <5 g/dl, 5-7 g/dl, and  $\geq 7 \text{ g/dl}$ . A paired Wilcoxon Ranked Sum test on the two-hour window comparing before and after transfusion was performed.

Our preliminary analysis determined that median HR significantly decreased after transfusion within a two-hour window, whereas median RR and SpO2 exhibited no significant difference. This study validates our unbiased, exploratory method for statistically identifying physiologic variables that change after transfusion. Initial generalized linear models that predict the post-transfusion states of these three variables have been created taking in a combination of the three variables with demographic information such as age, race, and sex as input variables. The correlation coefficients between the actual and predicted values of these models are 0.8009, 0.8157, 0.6497 respectively. It can be noted that the HR and RR models perform significantly better than the model for SpO2. Additional input variables will be incorporated and further models that predict a greater number of variables will be developed to better predict the physiologic state of the patients as well as the probability of adverse outcomes after transfusion.

# Quantitative Assessment of TMJD-Induced Sleep Disorders and Prediction of Therapy Effectiveness

**Team Members:** Samana AlGharbi, Archana Balan, Jiaqi Huang, Patrick Myers, Nausheen Tickoo

Advisors: Michael Smith, PhD; Sridevi Sarma, PhD; Joseph Greenstein, PhD; Abhishek Dave

Abstract: Temporomandibular joint dysfunction (TMJD) is one of the most common orofacial pain conditions, affecting an estimated six to 12 percent of the US population, primarily women. In addition to pain, the disorder is characterized by sleep disturbance, a major contributor to decreased life quality for patients. TMJD diagnosis is currently highly subjective and is based on three scores which are extracted from patient diaries and questionnaires administered by sleep specialists: Cognitive, Somatic and Pain Catastrophizing scores. This research study split patients into three therapy groups: Behavioral, Cognitive and TMJD education. However, current literature has not yet explored the correlation between the sleep scores and the available therapies. Furthermore, the shortage of certified sleep experts, the subjective nature of the questionnaires, and the absence of objective diagnosis contribute to the improper diagnosis and treatment prescription for TMJD patients. This study provides a quantitative approach to assess TMJD by exploring associated sleep factors as demonstrated by sleep surveys and physiological features extracted from patient polysomnography. Our current investigation has demonstrated correlations as high as 0.75, between specific biological markers and patient sleep scores. These physiological markers can be employed to provide a more quantitative diagnosis for patient TMJD status. They will then be utilized in a predictive model to identify the best therapy type for each patient. The implementation of this model could have significant clinical impact by requiring less specialized physicians to properly prescribe therapy to TMJD patients, eliminating the gap between needed and current sleep specialists.

#### Using Machine Learning Models to Predict the Likelihood of Patient Readmission to ICU

**Team Members:** Jack Wright, Ryan Hanks, Yang Zhao, Arman Koul, Jiaxin Lin

Advisors: Nauder Faraday, MD, MPH; Adam Sapirstein, MD; Sachidanand Hebbar; Joseph Greenstein, PhD; Raimond Winslow, PhD; Ran Liu



Abstract: Intensive care units (ICUs) cater to individuals with severe injuries and illnesses. Therefore, the patients within suffer from acute anatomic and physiologic derangements requiring constant monitoring and more intense support from hospital staff. Their conditions necessitate rapid diagnosis and intervention of abnormalities to facilitate a period of recovery. A challenge arises, however, in the recognition of sufficient resolution of the pathophysiologic state such that the patient can be safely discharged to a lower intensity environment. The decision to discharge is currently based on the expertise of ICU clinicians, but there is currently no formal method to assist clinicians in predicting a patient's chance of success or readmission, so this process is imperfect. As such, ICU readmission rates range from two to 20 percent. Readmission rates depend on a variety of factors, including demographic characteristics, comorbidities, severity of illness score, duration of index ICU stay, type of ICU, discharge destination, etc. Regardless of what factors led to readmission, a major problem manifests in the rates of in-hospital death for those who are readmitted to the ICU. Compared to patients who are successfully discharged, those who are discharged but return to the ICU are two to 10 times more likely to die in hospital. Unfortunately, current predictive models are insufficiently accurate. In general, these models are built on static parameters and don't take advantage of the large amount of complex data available in the EHR, nor do they take time varying covariates into account. So, generating an algorithm that is able to use all of the available data in order to accurately predict readmission to the ICU would have several important impacts. By improving physicians' ability to determine resolution of the pathophysiologic state and reduce premature discharge, we could expect morbidity and mortality rates to decrease as well as reduced healthcare costs for patients. Similarly, the information a predictive model provides would allow for better allocation of resources, by letting hospital staff know which ICUs have higher readmission rates and require more attention. Finally, the features examined during this project could potentially be generalized for use in future predictive models.

## Machine Learning-Based Prediction of Cardiac Arrest Outcome Using a Large Multi-Center Database

**Team Members:** Tatiana Gelaf Romer, Qingchu Jin, Hanbiehn Kim, Hieu Nguyen, Sharmila Tamby, Eric Sung

Advisors: Robert Stevens, MD; Jose Suarez, MD; Christian Storm; Raimond Winslow, PhD; Joseph Greenstein, PhD; Ran Liu

**Abstract:** Cardiac arrest (CA) is a leading cause of death and poses a significant risk of long-term neurological disability due to hypoxic-ischemic encephalopathy. There is a large unmet need for accurate and reliable methods to predict post-CA neurological outcomes and treatment responses. Our goal is to predict the probability of neurological recovery using a database of patients admitted to 208 hospitals in the US. Aims are twofold: (1) to compare the predictive performance of models using features extracted from electronic health records (EHR), from physiological time series (PTS), and models combining EHR and PTS features; and (2) to contrast predictive performance obtained with different statistical and machine learning models.

We analyzed data collected in the first 24 hours following ICU admission. Outcome was the motor subscore of the Glasgow Coma Scale (GCS) at the time of discharge from the ICU (good: six, poor: one through five). From 240,000 ICU admissions, 2,216 CA patients were selected based on the following inclusion criteria: alive for > 24 hours, mechanical ventilation, and motor GCS recorded within 24 hours of ICU discharge. Missing data was imputed using population mean and linear interpolation. 452 predictive features were identified based on prior knowledge of variables perceived as impactful on CA outcome. Feature selection was performed using random forest and LASSO regularization. We evaluated the predictive performance of a generalized linear model (GLM) and several machine learning models, including random forest, support vector machine, gradient boosting, and neural networks.

Our best performing model was GLM that achieves an average 0.846 AUC, 0.798 sensitivity, and 0.742 specificity. This model had higher discrimination than models trained with APACHE IV variables (AUROC ~0.70). The top ranked features selected using LASSO regularization include GCS score upon admission; worst motor and eye GCS score within 24 hours; maximum lactate, albumin, MCHC, and alkaline phosphate; and mean respiratory rate.

These findings indicate that a machine learning model applied to a large clinical dataset can predict post-CA outcome with a level of accuracy that surpasses APACHE, the current standard for ICU prediction. Results also indicate PTS features boost model performance. In addition, several previously overlooked predictive features were identified which merit further investigation.

### An Apparatus for Precise Data Collection from Stroke Patients

#### Independent Designer: Jihoon Jang

Advisors: Reza Shadmehr, PhD; Amir Manbachi, PhD; Scott Albert

**Abstract:** One out of 20 deaths in America are caused by stroke: on average. American suffers from stroke every 40 seconds. For those that survive, physical therapy can cost up to 17,000 dollars during the first year of rehabilitation, and can take months to years to complete. Overall, Americans pay 34 billion dollars for rehabilitation. Research is being conducted around the world in order to improve rehabilitation outlooks as well as decrease the time and money necessary. At the Laboratory for Computational Motor Control (LCMC), researchers study motor learning in human subjects by having participants manipulate a robotic arm in order to perform various movement and holding tasks. Data such as force, velocity, and position are collected and analyzed during these experiments so that models can be generated to characterize motor control in humans. For participants with stroke, these results are often noisy or impossible to collect due to their symptoms. In order to improve data collection, we will design a non-invasive apparatus to attach to the robotic arm in order to aid patients during the use of the robotic arm by accommodating for their physical impairments. This will lead to the generation of improved models of stroke patient motor control that will lay the groundwork for innovations in faster and cheaper rehabilitation strategies.

# Redesigning Scrambler Therapy: A Neuropathic Pain Treatment Device

#### Independent Designer: Nicholas Sass

Advisors: Allan Belzberg, MD; Michael Caterina, MD, PhD; Amir Manbachi, PhD; Yun Guan, MD, PhD; Thomas Smith, MD

Abstract: Neuropathic pain effects between seven and ten percent of Americans; it lowers patients' productivity, ability to sleep, and general guality of life. The discomfort is caused by physical damage to a nerve, but the exact source is difficult to pinpoint. Even more challenging is treating the pain, which is highly resistant to physical or pharmaceutical relief. We are building a device that aims to improve the effectiveness of Transcutaneous Electrical Nerve Stimulation (TENS) devices. TENS devices treat pain by delivering a small and painless electrical current through electrodes placed on the body near the source of pain. The current stimulates nearby healthy nerves to shut down the damaged nerve, a process described by Melzack & Wall's Theory of Gate Control. Current devices benefit from low side effects, ease of use, and affordability, but tend to lose relief effectiveness over time. Our device, TENS Advanced. maintains relief over the long term by delivering an electrical current based on a high-variability algorithm. Similar products have shown some success, and we plan to clarify both what kinds of signal variation provide the most relief and the physiological effects of the treatment.

#### **Redesign of the Orthopedic Walking (CAM) Boot**

#### Independent Designer: Grace Kuroki

Advisors: Amir Manbachi, PhD; Stephen Belkoff, PhD; Jason Hammond, MD; Jane Webster; Charlotte Webster; Joshua De Souza

**Abstract:** One of the best parts about being a young adult is feeling invincible, pushing one's boundaries to the extremes. However, this leads to a series of injuries, particularly in ankles. In patients 19 or younger, sports related injuries rank as the second highest source of ankle fractures. According to Dr. Jason Hammond, orthopedic surgeon at Union Memorial Hospital, the most common reason for a prescription orthopedic walking boot is a non-surgical solution to tendonitis and small fractures in the ankle/foot. These patients will wear the boot from two to six weeks, depending on the severity of the injury. But, up to 80% of patients discontinue using their orthopedic shoes or devices before suggested end time, with the majority of concerns ranging from function to aesthetic complaints. The major issues of the current design of the boot are: the poor fit, heavy weight, bulky size, lack of options for warmer climates, displeasing appearance, and most importantly, unacceptable discomfort. Even though these boots are not one-size fits all, their sizing selection and current design leave most users dissatisfied and left with further pain. Due to the lack of availability in customization and desire to discontinue wear, there is a need for a walking boot that can be optimized for the athletic young adult and adolescent age group to maximize recovery in a minimum amount of time for non-surgical patients with small fractures.

## A BioMEMS Sensor for Monitoring and Controlling Biological Fluid Flow

#### Independent Designer: Walter Zhao

Advisors: Soojung Claire Hur, PhD; Amir Manbachi, PhD

**Abstract:** Hydrocephalus is a neurological condition caused by excess cerebrospinal fluid (CSF) within the cerebral ventricles. With symptoms ranging from nausea and lethargy to seizure and coma, untreated hydrocephalus results in severe loss of quality of life and death. Over one million people in the United States currently suffer from hydrocephalus, with 75,000 new cases each year. Of these, 20% are children: with one in 500 children being born with the disease, congenital pediatric hydrocephalus is as common as Down syndrome.

Current treatment implants a shunt to redirect CSF to another region of the body such as the peritoneal cavity or heart. However, shunts fail easily, with 50% malfunctioning within two years of use. Attempts to improve shunts have failed to alleviate this issue, with a hydrocephalus surgery occurring every 15 minutes. Standard diagnosis involves medical imaging and an invasive "shunt tap" procedure that risks infection. As these methods rely on a single measurement and require physician expertise, they are insufficient for long-term monitoring. Many patients effectively "rotate into the ER every seven months" to check their shunt, leading to large medical costs. A way to remotely and continuously detect and modulate shunt behavior is needed to improve patient quality of life and reduce strain on the healthcare system.

QuantiShunt is an innovative approach to treating hydrocephalus, allowing both patients and physicians to monitor shunt status in real time. Combining precise sensing capabilities and machine learning algorithms, our solution will enable patients to lead engaging and worry-free lives while allowing physicians to better personalize treatment to optimize patient well-being.

#### **Oravi: Immersive Virtual Environments for Language Learning**

Team Members: Prasiddha Karki, Joseph Naness

Advisors: Anton Dahbura, PhD; Amir Manbachi, PhD

**Abstract:** Acquiring fluency in a foreign language is a challenging prospect, yet many people desire to do so for a variety of reasons. Millions of people use language learning software like Rosetta Stone and Duolingo in order to achieve this goal. Unfortunately, these popular programs are unable to effectively provide the experience gained by speaking with other people in a foreign language. Having a speaking partner is not a readily available option for many language learners, so practicing conversational skills can be difficult. This project aims to provide a solution to this problem in the form of software that simulates conversations in a foreign language. Oravi places users in virtual environments that simulate conventional scenarios in foreign settings. With the use of advanced speech recognition technology, users are able to speak to and have conversations with any of the characters in the environments. Oravi provides a means for language learners to practice and assess their speaking skills in a way no other language learning software offers.

# **ADVANCED DESIGN PROJECTS**

#### **Relavo: Reducing the Incidence of Peritonitis in Peritoneal Dialysis**

**Team Members:** Anna Bailey, Tejasvi Desai, Giang Hoang, Sarah Lee, Eugene Oh, James Qin

Advisors: Alicia Neu, MD; Elizabeth Logsdon, PhD; Tom Benassi; Barbara Case, RN; Paul Fearis, MDes; William Clarke, PhD

**Abstract:** End-stage renal disease (ESRD), also known as kidney failure, is a disease that affects more than 700,000 people in the United States alone and requires them to receive a form of renal-replacement therapy (RRT). One form of RRT is peritoneal dialysis (PD), which patients receive at home every night. While PD is associated with improved health outcomes and higher quality of life compared to hemodialysis (HD), the most common form of RRT, clinicians recommend the majority of patients to receive HD. This is due to the high associated risk of peritonitis, an infection of the peritoneal membrane commonly caused by touch contamination during the PD set up process. Peritonitis has an incidence of one episode per four patients per year, with 60% of episodes leading to hospitalization. These infections cost the US healthcare system over \$105 million each year.

Relavo is combating these infections by developing the PeritoneX, a device that disinfects contaminated tube ends after all connections have been made. By minimizing the risk of peritonitis, we reduce the reliance on patients to comply with sterile procedure. The PeritoneX allows patients to receive higher quality care, and reduces peritonitis treatment expenditures for dialysis providers and insurance payers.



# **ADVANCED DESIGN PROJECTS**

## Quantishunt: Identifying Malfunction in Cerebroventricular Shunts

Team Members: Daphne Schlesinger, Ryan Najmi, Vinay Ayyappan, Dante Navarro, Walter Zhao, Shayan Hemmati, Anneka Kleine, Helen Wiegand

Advisors: Mark Luciano, MD, PhD; Amir Manbachi, PhD; George Coles, MSE; Joseph Katz, PhD; Susanna Thon, PhD

**Abstract:** Hydrocephalus, a disease characterized by buildup of cerebrospinal fluid (CSF) within the cerebral ventricles, is treated via the placement of a shunt that redirects fluid to an epithelium-rich region of the body. While shunts do alleviate chronic hydrocephalus symptoms, they frequently malfunction with potentially fatal consequences. Existing methods for detecting failure require an extensive workflow that may culminate in surgical intervention. Moreover, generic symptoms resulting from shunt malfunction cause many patients to incorrectly self-diagnose, leading to unnecessary treatment, risking complications and infection. A simpler, objective detection method is needed to prevent the occurrences of missed failures and false positives. Here, we characterize the mechanical behavior of cerebral shunts and report that valve drainage is linearly proportional to flow independent of shunt orientation. Additionally, we present the design and large-scale evaluation of a device employing a capacitive sensing method to monitor shunt status. Such a device would be able to track drainage in real-time, enabling quick and accurate identification of shunt status.



# **ADVANCED DESIGN PROJECTS**

#### **Osteocast: Improving Distal Radius Fracture Management**

Team Members: Shipra Khatri, Victoria Chen, Nikhil Murty, Ronak Mahatme

Advisors: Amir Manbachi, PhD; Ryan Hurley, PhD; Jason Hammond, MD; Tom Benassi; Stephen Belkoff, PhD; Jane Webster

**Abstract:** There are approximately six million hospitalizations with fracture diagnoses per year. For adults, 50% of all reported fractures occur in the arms. This amounts to a market of over \$2 billion for the treatment of over three million cases in the United States per year. A fracture is caused by a bone experiencing a force greater than it can absorb. In order for the bone to heal, the fracture needs to be realigned and immobilized to maintain the bone's natural anatomical alignment and protect against additional impacts and possible refracture. This is normally done with a plaster or fiberglass cast. It is well known that patients experience discomfort with the itchiness, sweating, and a lack of water resistance of the current casts, and some efforts have been made to address this. In addition, one overlooked issue of fracture management is cast loosening or tightening that occurs due to changes in swelling of the arm. This issue forces patients to go through up to two replacement casts, with each visit taking 30 minutes. This takes away valuable time from both doctors and patients.

Osteocast is an auto-adjustable device that accounts for changes in swelling that occur throughout the fracture management process. The device can automatically loosen and tighten in response to changes and swelling, while remaining stiff. This enhances stabilization and prevents the risks associated with refracture of the bone. This novel, wearable technology will eliminate the need for extraneous visits to the clinic, allowing patients and physicians to navigate fracture management with greater efficiency and ease. Furthermore, the device incorporates waterproof, breathable materials in order to solve patient complaints that result from discomfort, itching, and lack of hygiene that is experienced with fiberglass casting.



# ABOUT JOHNS HOPKINS BME ENGINEERING THE FUTURE OF MEDICINE

The mission of the Johns Hopkins University Department of Biomedical Engineering is to advance human health by training biomedical engineers who will lead in **Engineering the Future of Medicine** through scientific discovery, translational research, and innovation that transforms healthcare delivery at scale.

Hopkins BME has defined the field of biomedical engineering for more than 50 years and continues to lead the way through BME 2.0, a next-generation curriculum that brings our pioneering research discoveries into our academic programs. With our faculty experts, Hopkins BME students are advancing medical knowledge, inventing biomedical technology, and improving patient care worldwide. Together, we are developing the technologies that cure disease.

**Education.** Consistently ranked #1 in the nation, our BME 2.0 academic programs create an integrative learning experience in which every student is an active participant in our discovery, innovation, and translational efforts. Through project-based courses, research, design opportunities, and more, our students





work with and learn from the leading engineers, scientists, and clinicians of the Johns Hopkins schools of Engineering, Medicine, and Public Health. Students specialize in one of seven disciplines at the forefront of biomedical engineering, applying their knowledge to solve real clinical, design, and engineering problems like the projects that you will hear about today.

**Research and discovery.** Hopkins BME faculty and students are pushing the boundaries of research and discovery, pioneering new disciplines with immense potential to bring about the groundbreaking health discoveries of the 21st century: biomedical data science, biomedical imaging, computational medicine, genomics & systems biology, immunoengineering, neuroengineering, and translational cell & tissue engineering. At the same time, these research areas drive our education, forming the basis of our BME 2.0 curriculum and informing our design projects.

**Innovation and translation.** Our goal is to improve people's lives by translating our research discoveries into technologies that cure disease and improve human health. With our clinical and industry partners, BME faculty and students are building a strong foundation for translating biomedical engineering discoveries into first clinical use and ultimately leading the application of new advances to human health.

We encourage you to support our student teams by visiting their posters and viewing their work. Thank you for celebrating their achievements with us at BME Design Day!



## BME 2.0 is transforming biomedical education through:

- **BME Basecamp.** BME 2.0 begins with a freshman experience that teaches students the fundamentals of the life sciences and mathematics, and introduces them to the principles of design and experimentation. Starting on day one, students have the opportunity to join one of the 3,000 basic science and clinical research labs at Johns Hopkins or work in our nationally recognized BME Design Studio, a world of discovery, innovation, and translation.
- **BME Bootcamp.** Building on the foundation of BME Basecamp, sophomore year begins an immersive education in quantitative analysis, with courses in statistical physics, signals, systems, controls, and modeling. BME Bootcamp trains students to model and engineer biological systems at the molecular, cellular, and organ levels using analytical approaches, preparing students to engage the biomedical challenges that they will encounter throughout the BME 2.0 curriculum.



## BME 2.0: THE FUTURE OF BIOMEDICAL ENGINEERING EDUCATION

The Department of Biomedical Engineering at Johns Hopkins University is training the next generation of leaders through BME 2.0, the biomedical engineering curriculum of the future. Through project-based learning, research experiences, and design opportunities, our students are solving real engineering problems, from their first day of freshman year until their graduation day.

- BME Residency. In their junior year, students become experts in one of seven modern BME disciplines through specialized focus area courses, based on our pioneering research. Working in teams, students solve real clinical and engineering problems through project-based courses related to their focus area. Courses in data science and computational medicine train all BME students to answer questions of health and disease using complex biomedical datasets.
- BME Practice. During senior year, advanced focus area courses seamlessly integrate students into the BME community at large. Advanced Design, Advanced Research, and other specialized projectbased courses allow students to complete the transition from the classroom to the bench and bedside. Through these opportunities, Hopkins BME students are **Engineering the Future of Medicine**.

#### **DESIGN EDUCATION AT HOPKINS BME**

The Johns Hopkins Department of Biomedical Engineering offers several opportunities for undergraduate and graduate students to continue **Engineering the Future of Medicine** by applying design principles to important medical and research challenges through team-based projects. Starting with a single team more than 20 years ago, our design programs have grown to include 17 undergraduate, eight master's, and five advanced design teams that will comprise more than 150 students next year, all focused on healthcare challenges. We have also expanded to offer five additional project-based design courses focused on a variety of clinical and research topics that, together, support more than 15 student teams. Learn more about the programs and courses featured at the 2019 BME Design Day.

#### The Undergraduate Design Team Program

Founded by Hopkins BME faculty in 1998, our Design Team program was the first in the nation to offer a longitudinal, team-based design course that incorporates freshmen through seniors. Working with clinical, industry, and faculty experts, students follow an iterative design approach to solve real-world problems in healthcare and medicine. As they develop their functional prototypes and devices, Design Team students experience clinical immersion, have opportunities to work with industry experts, and incorporate concepts related to intellectual property, regulatory frameworks, business plan development, and more. Since 2015, our undergraduates have generated:

- More than \$650,000 in funding
- 11 provisional patent applications
- $\cdot$  19 journal and conference papers
- 60 awards—and counting
- 6 new startup companies

### David E. Swirnow MSE in Bioengineering Innovation and Design (CBID)

This year marks the 10th anniversary of our leading master's degree program in the design of healthcare solutions, offered through the department's Center for Bioengineering Innovation and Design (CBID). This program trains the next generation of leaders in healthcare innovation by guiding them to identify and create solution concepts for pressing challenges both here and globally, through an iterative process that includes detailed analysis, concept generation, prototyping, pre-clinical assessment and refinement, and commercialization planning. The program benefits from a rich clinical experience, robust industry partnerships, and a global immersion including international travel. Since it began in 2009, the CBID MSE program has resulted in:

- 84 advanced healthcare systems and global health projects
- Partnerships with 26 clinical departments and 180 project mentors
- · 12 healthcare startup companies
- More than \$25 million in equity investments and grants
- Multiyear partnerships with 10 leading medical device companies
- Support from leading global health funders, including USAID, BMGF, and Aspen Institute

#### **Project-based Courses for Undergraduate and Graduate Students**

#### Precision Care Medicine

Students apply machine learning and mechanistic and statistical modeling to develop data-driven solutions to healthcare problems that arise in anesthesiology and critical care medicine, including determining when patients should be admitted to or discharged from intensive care units, predicting changes in the state of patient health, and selecting optimal patient therapies. Teams work with faculty from the Johns Hopkins Institute for Computational Medicine and the departments of Anesthesiology & Critical Care Medicine, Neurology, and Psychiatry & Behavioral Sciences to design, validate, and deploy applications that deliver computational methods to address underlying healthcare problems.

#### Introduction to Rehabilitation Engineering

Students work in teams to develop new and improved needs-based devices to be used for measurement or treatment of an impairment or disability. In doing so, students learn the biomedical engineering design process and its application to those with disabilities.

#### Independent Design

Students work to design and evaluate a system that demonstrates creative thinking and experimental skills, and draws upon advanced topics of biomedical and traditional engineering.

#### Advanced Design

This course is the follow-up to our undergraduate Design Team course sequence. It provides project-specific mentorship and guidance for a team of students to complete a sophisticated prototype and demonstrate technical feasibility towards impacting a clinical problem. Allowing projects to continue as part of the curriculum beyond the first year of Design Team provides support for more advanced testing, de-risking, funding applications, and translation.



#### **2019 JOHNS HOPKINS HEALTHCARE DESIGN COMPETITION**

With generous support from Boston Scientific and Johns Hopkins Technology Venture's FastForward, CBID hosted the annual Johns Hopkins Healthcare Design Competition on April 14 at the Homewood campus. More than 130 international teams submitted project proposals to one of three tracks: Advanced Health Systems, Global Health/Humanitarian Design, or Health App/Information Technology. Of these, 31 teams were selected to present their business plans and project designs at the event for a chance to win cash prizes, totaling more than \$24k, that will support the winning teams as they further the research, design, and implementation of their projects.

The finalists represented more than 19 institutions, including Johns Hopkins University, Georgia Institute of Technology, University of Pennsylvania, Rice University, Medical College of Georgia, Bangladesh University of Engineering & Technology, and more.

The winners of the 2019 Healthcare Design Competition are:

#### Advanced Health Systems

- First Place: SecURO (Georgia Institute of Technology)
- Second Place: Tiny Stitch (Rice University)
- Third Place: CortiTech (Johns Hopkins University)
- Future Innovators: D<sup>2</sup>NK (Somers High School)

#### Global Health/Humanitarian Design

- First Place: ForSight Innovation (Johns Hopkins University)
- Second Place: Colostomates (Rice University)
- Third Place: Eyedea Medical (Johns Hopkins University)

#### Health App/Information Technology

- First Place: Fitalyst (University of Pennsylvania)
- Second Place: Team SIPO (Bangladesh University of Engineering & Technology)
- Third Place: R6 Industries (Medical College of Georgia)



The mission of CBID is two fold. First, we are dedicated to education and development of the next generation of leaders in medical innovation. The ideas described in this brochure are the result of the hard work of these students and the clinicians and faculty who have guided them throughout the year.

The second part of our mission is to improve health. Each team addresses a significant health care need with a solution that can have a life-changing impact on many people around the world and here at home.

We invite you to consider supporting these teams. There are a number of ways you can have an impact through CBID. We need business mentors, clinical mentors, technical mentors, and of course, financial support to make all of this possible.

We welcome your partnership and support!



#### WITH GENEROUS FINANCIAL AND IN-KIND SUPPORT FROM:







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