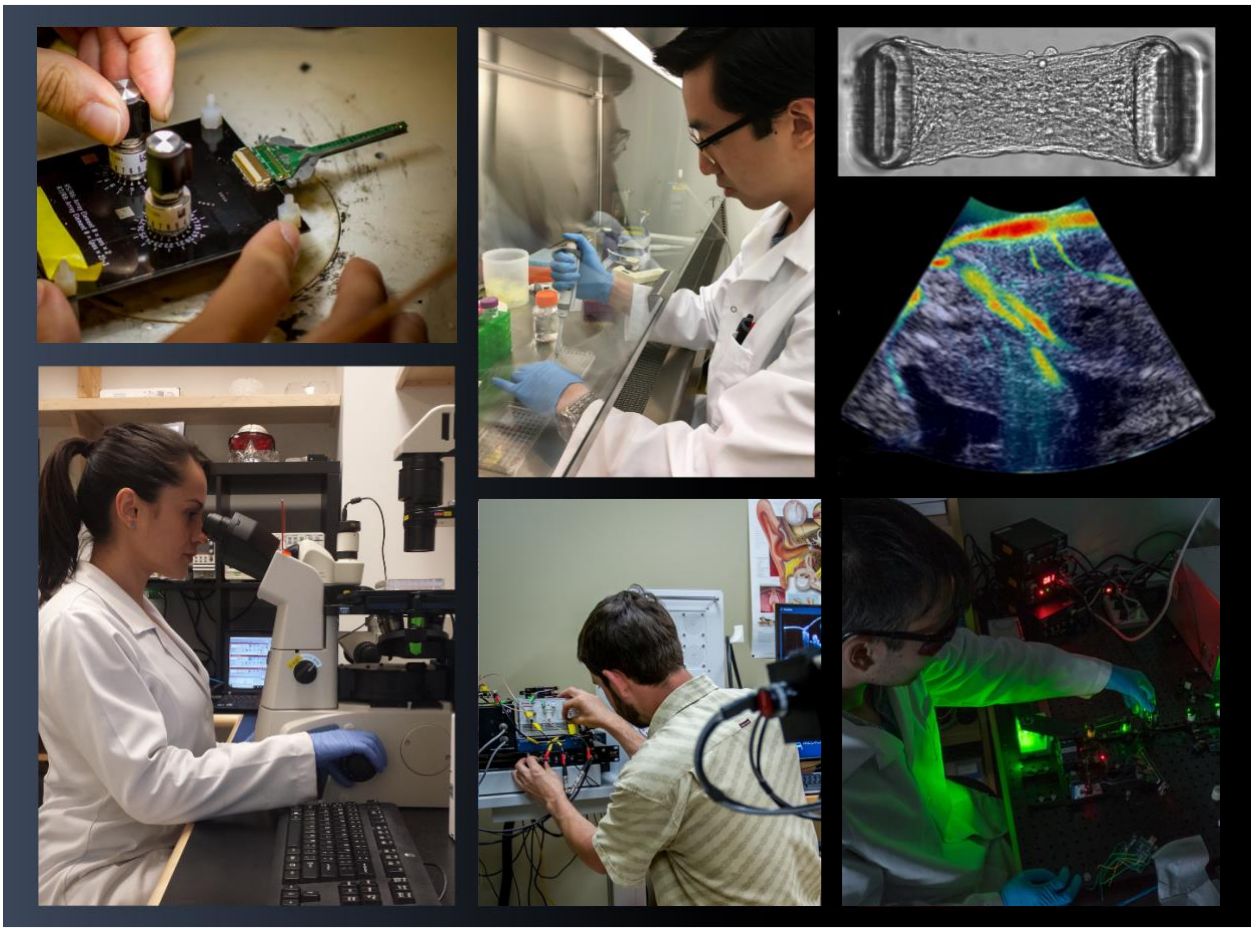
School of Biomedical Engineering

Research Day 2020



Scientific Program

DALHOUSIE UNIVERSITY

DALHOUSIE UNIVERSITY

June 9, 2020

Dear Colleagues:

It is my pleasure to welcome you to the 18th Annual Research Day of the School of Biomedical Engineering at Dalhousie University!

I want to start by saying how continually proud I am of the people of our School and in particular of our students. These past months and Research Day are different because of the restrictions necessarily in place due to the pandemic. It's a challenging time and the Dalhousie Biomedical Engineering Student Society has responded by moving their community online. The DBES has been very active in thinking creatively how to bring us together. Our School seminar series is online and is now supplemented by fantastic DBES organized Town Halls for the students. So far these normally feature discussions with members of our Faculty, sharing experience and knowledge of their profession drawing largely from their personal experiences. In addition, this Research Day is largely going forward because of the shared enthusiasm to get together and share our science together from our students.

The SBME Research Day is an important experience both for the presenters and for the audience. Our student presenters get to present their research at varying stages in progress. They are getting a chance to see what it takes to frame their research questions and results in the conference talk format. In my experience this is useful in so many ways. For me it's primarily a chance to think again of the big picture, explain why I am doing what I am doing and describe what is really interesting from the results so far. It gives focus to a larger project. But also, it's a chance for your peers to give back, to give feedback by asking questions. This can give a new insight as to what may be more interesting than previously thought (and may also give what might need more thought to be more interesting - constructively!)

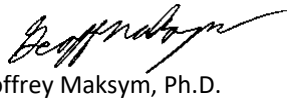
Thus, I encourage each of you, and especially the students, to participate and engage with each other through helpful comments and questions. Since it is online it is harder to 'feel the audience' during or after a talk, so show your appreciation - use the clap hands, or unmute your mic and clap – it will be meaningful to those presenting. And if there is no time for your question during the session, or you had something you wanted to ask but thought of it later – please send it to the presenter afterwards. This would normally be easy to do as you encounter your peers naturally, but now it's important to try to reach out via email/phone/teams etc. – our communities benefit from communicating!

I want to sincerely thank all those who put this day together. Thank you to the PREP Research Day coordinators who helped put the larger two-day event together including the cross-disciplinary COVID-19 research panel, the Gairdner award winner plenary speaker Elaine Fuchs, the Research Excellence award winners. And for putting our Research Day together - thank you to Brendan Leung, Sam Veres and Heather Harris for their help organizing the sessions today and online and as always, a big thank you to Sandra Pereira who helped us all and me tremendously with many of the details and particularly helping me prepare the awards.

After the presentations, I am looking forward to the opportunity to acknowledge members of the SBME community and announce our annual SBME awards. Please join me and congratulate our award winners.

And finally, we are inviting everyone to stay online for a social get-together after the science and awards are all done. I am not sure yet how that will work, but we won't know until we try – so grab a drink or snack and join us on Zoom for some socializing at the end of the day!

Welcome to all!



Geoffrey Maksym, Ph.D.
Professor and Director

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Previous Winners of the Community Builder Prize in Biomedical Engineering

2008

Marianne Ariganello

2011

Adrian West

2013

J. Michael Lee

2015

Eleanor Seaman-Bolton

2017

Rishima Agarwal

2018

Kristin Robin Ko

2019

Tyler Herold

Previous Winners of the Annual Teaching Prize in Biomedical Engineering

2008
Geoff Maksym

2009
J. Michael Lee

2010
Jeremy Brown

2011
Paul Gratzer

2012
Rob Adamson

2013
Janie Astephen-Wilson

2015
Daniel Boyd

2016
Sarah Wells

2017
Jeremy Brown

2018
John Frampton

Previous Winners of the George W. Holbrook Prize in Biomedical Engineering

2010
Richard Roda

2011
Graeme Harding

2013
Matthew Walker

2014
Pouya Amiri

2015
Lauren Kiri

2016
Brandon Scott

2017
Kristin Robin Ko

2018
Rishima Agarwal

Previous Winners of the Allan E. Marble Prizes in Biomedical Engineering

2002
Sean Margueratt

2003
Anna Dion

2005
Doctoral: Mark Glazebrook
Pre-doctoral: Carolyn Lall

2006
Doctoral: Scott Landry
Pre-doctoral: Scott MacLean

2007
Doctoral: Janie Astephen
Pre-doctoral: Andrew Moeller

2008
Doctoral: Marianne Ariganello
Pre-doctoral: Vargha Talebi

2009
Doctoral: Jack Fairbank
Pre-doctoral: Jennifer Krausher

2010
Derek Rutherford

2012
Del Leary

2013
Andre Bezanson

2014
Caitlin Pierlot

2015
Arash Momeni Boroujeni

2016
Dan MacDougal

2017
Brett Dickey

2019
Alyne Teixeira

School of Biomedical Engineering

PREP 2020 (Virtual) SBME Research Day 2020 Scientific Program – Via Zoom

Tuesday, June 9, 2020

Afternoon Session	
2:30 pm to 2:45 pm	**Welcome: Dr. Geoff Maksym, Director, School of Biomedical Engineering**

Scientific Session 1 (Chairs: Kelsey Gsell and Meghan Martin)	
2:45 pm to 3:00 pm	***"Simple and Cost-Effective Immunoassays Facilitated by Aqueous Two-Phase System Reagent Confinement"*** **Alyne Teixeira (PhD Student), Maia Kvas, and John P. Frampton**
3:00 pm to 3:15 pm	***"Capabilities of an Ultrafast High-Frequency Hardware Beamformer for a Phased Array Endoscope?"*** **Nicholas Campbell (PhD Student), C. Samson, and J.A. Brown**
3:15 pm to 3:30 pm	***"Upper Extremity Agonist-Antagonist Myoneural Interface For Improved Prosthesis Control"*** **Rakesh Gudimella (MASc Student), Robert Adamson, and David Tang**

Coffee Break (3:30 pm – 3:45 pm)

Scientific Session 2 (Chairs: Kelsey Gsell and Meghan Martin)	
3:45 pm to 4:00 pm	***"Fabrication and characterization of a synthetic mucus layer for mammalian-microbial co-culture application"*** **Andy Hung (MASc Student), and Brendan Leung**
4:00 pm to 4:15 pm	***"A Tri-Frequency Endoscopic Ultrasound Transducer for Combined Imaging and Therapy"*** **Matthew Mallay (PhD Student), T. Landry, J.K. Woodacre, J.A. Brown**
4:15 pm to 4:30 pm	***"Investigating the Origin of the Frequency Dependence of Respiratory Resistance to Airflow in Disease – Application to Lung Transplant"*** **Anas Tahir (PhD Student), Alex Brezovan, Paul Hernandez, Andrew Ros and Geoff Maksym**

Awards and Closing	
4:30 pm	**School of Biomedical Engineering Awards and Closing Remarks** **Chair: Dr. Geoff Maksym**

Closing virtual Reception Via Zoom

School of Biomedical Engineering
Research Day 2020 Abstracts
SCIENTIFIC SESSION 1

Simple and Cost-Effective Immunoassays Facilitated by Aqueous Two-Phase System Reagent Confinement

Alyne G. Teixeira[a], Maia Kvas[a], and John P. Frampton[a,b]

[a]School of Biomedical Engineering, Dalhousie University, Halifax, Nova Scotia, Canada; [b]Department of Biochemistry and Molecular Biology, Halifax, Nova Scotia, Canada

Immunoassays have numerous biomedical applications, but the high cost of biologic reagents represents a significant bottleneck in terms of the ability to apply immunoassay approaches in scenarios where resources are limited. Here, we examined the potential to address this drawback for single sandwich ELISA and enzyme linked immunospot (ELISpot) using aqueous two-phase systems (ATPSs): PEG-dextran and PEG-bovine serum albumin (BSA).

The first system is composed of 20% dextran-20% PEG, and the second system is composed of 7% PEG-10% BSA. For single sandwich ATPS-ELISA, we assessed performance characteristics such as limit of detection and linear dynamic range. For ATPS-ELISpot, we assessed the limit of detection, immune cell cytotoxicity, immune cell morphology, and cytokine secretion for both the PEG-dextran ATPS and the PEG-BSA ATPS. We also assessed the agreement between the conventional immunoassays and ATPS-ELISA and ATPS-ELISpot techniques by Bland-Altman analysis and determined the costs of these novel assay formats in comparison to the conventional approaches.

The PEG-dextran system minimized consumption of antibodies in single sandwich ELISA, with comparable performance characteristics to conventional single sandwich ELISA. In ELISpot, both systems did not affect cell viability or stimulate secretion of cytokines over 24 hours. These results suggest that the PEG-dextran and PEG-BSA systems do not harm or activate the cells. Both systems were able to confine immune cells and reagents, producing comparable performance characteristics to conventional ELISpot, while reducing the amounts of cells and reagents. We demonstrated that both ATPSs can improve the cost-effectiveness of immunoassays such as ELISA and ELISpot.

References: [1]Li, H., et al. *Sci. Rep.* 5, 11688 (2015); [2]Frampton, J.P., et al. *Sci. Rep.* 4, 4878 (2014); [3]Simon, A.B. et al., *Technology*, 2(2):176 (2014); [4]Eiden, L., et al. *Anal. Chem.* 88(23), 11328-11334 (2016).

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Capabilities of an Ultrafast High-Frequency Hardware Beamformer for a Phased Array Endoscope

N.A. Campbell[1], C. Samson[1], J.A. Brown[1],

[1]Depeartment of Biomedical Engineering, Dalhousie University, Halifax, Canada

Background, Motivation and Objectives

Most ultrasound systems implementing plane wave and diverging wave beamforming use hardware to collect ultrasound channel data, but typically will perform the beamforming and compounding steps in software on a PC/GPU. Due to the high data bandwidths, it is challenging to implement ultrafast imaging techniques at real-time display framerates, eg, shear wave elastography, Ultrafast Doppler, etc.

Statement of Contribution/Methods

In this study, a custom 64 channel hardware-based beamformer generates multiple ultrafast frames at a 0.7KHz frame rate while maintaining a real-time (20 Hz) software display frame rate using a single USB
3.0 data link. The designed beamforming platform controls a 40 MHz, 64 element phased array endoscope for guiding minimally invasive procedures. Firmware on the receive daughter cards Field Programmable Gate Arrays (FPGAs) performs upsampling, filtering, ultra-fast diverging wave beamforming, and frame compounding. The receive motherboard FPGA collects and compounds the frames from the daughter cards. The Motherboard facilitates the real-time display of frames to a P.C.

Results/Discussion

The bandwidth between the motherboard and daughter card limited the frame rate to 700 Hz. The parallel beamforming data rate achieved to the Motherboard was 610.7 Gigabits/s while collecting a 65,536-pixel, 16-bit image from each receive daughter card using 32 diverging waves. Real-time images of a point target and in vivo images of a human wrist were generated. Improvements to the speed of the hardware beamforming data throughput could potentially increase the frame rate to the 1.25 kHz frame rates, which would correspond to the time of flight limitation for the pulse repetition frequency.

Upper Extremity Agonist-Antagonist Myoneural Interface For Improved Prosthesis Control

Rakesh Gudimella, Rob Adamson, and David Tang

[1]Depeartment of Biomedical Engineering, Dalhousie University, Halifax, Canada

Purpose

Current hand prostheses have limited sensory feedback resulting in poor dexterity and prosthesis abandonment. To address this, we aim to utilize proprioception as a novel sensory feedback modality after hand amputation using the agonist-antagonist myoneural interface (AMI). AMI is a surgical technique reported in the lower extremity to improve proprioception, prosthesis embodiment and function, but has not been adopted for the upper extremity. We present the first case of AMI after hand amputation.

Methods

AMI involves the creation of an internal joint by coapting agonist and antagonist muscles over a gliding surface. Contraction of a muscle imposes strain on its antagonist muscle, restoring their biomechanical relationship and improving proprioception. In a patient with hand amputation, we performed a transradial amputation with AMI. A smooth surface for tendon gliding was created using an extensor compartment flap as a large central pulley. Agonist and antagonist muscles were passed through the central pulley and subsequently joined with normal muscle tension determined by ultrasound examination of the contralateral limb.

Results

After one week, the patient reported no phantom limb sensations or adverse events apart from minor tenderness at the operative site. At two weeks and 6 months, ultrasound examination showed tendon gliding within the central pulley. The patient reported high levels of embodiment and demonstrated intuitive prosthesis function without previous training, an improvement over standard amputation.

Conclusions

We report a successful case of upper extremity AMI following wrist disarticulation. This technique could redefine the future of amputation surgery to enhancing prosthesis use.

School of Biomedical Engineering
Research Day 2020 Abstracts
SCIENTIFIC SESSION 2

Fabrication and characterization of a synthetic mucus layer for mammalian-microbial co-culture application

Andy Huang[1], Brendan Leung[1,2]

[1]School of Biomedical Engineering, Dalhousie University, [2]Department of Applied Oral Sciences, Faculty of Dentistry, Dalhousie University

Introduction: Moist surfaces of the human body exposed to the external environment are lined with a biological hydrogel known as mucus, composed mainly of water and a network of glycoproteins called mucin. This mucus provides a unique microenvironment for bacteria-bacteria and host- bacteria interactions. We have developed a simple and robust technique to study these interactions in vitro using aqueous two-phase systems (ATPS) for a controlled mammalian microbial co-culture. One of the most used ATPS formulations consists of polyethylene glycol (PEG) and dextran (DEX). Bacteria can be suspended in DEX-rich phase and deposited onto a mammalian monolayer cultured in PEG-rich phase. The interfacial tension between the two phases serves to confine bacteria within the DEX-rich phase, thus limiting planktonic overgrowth. However, PEG poses toxicity towards mammalian cells over long culture periods (>2 days). The aim of this project is to provide a realistic mucus environment for cellular interaction and mitigate PEG-mediated cytotoxicity by incorporating a synthetic mucus layer.

Methods: Human bronchial epithelial cells (16-HBE) were grown to confluency and overlaid with an alginate-mucin semi-interpenetrating polymer network (Alg-Muc semi-IPN) hydrogel. Mucus mimic hydrogels were fabricated by using a simple calcium chloride ionic gelation technique. Two ATPS formulations, consisting of 5% PEG/5% DEX and 10% PEG/10% DEX (w/v), were prepared. The effectiveness in mitigating PEG-mediated cytotoxicity was evaluated using a Live/Dead Assay.

Result and Conclusion: Using an Alg-Muc semi-IPN we can mitigate PEG-mediated cytotoxicity. We also show that these hydrogels are highly tunable to generate various stiffnesses while recreating the selective diffusional barrier function of natural mucosal layer.

A Tri-Frequency Endoscopic Ultrasound Transducer for Combined Imaging and Therapy

M. Mallay1, T. Landry1, J. K. Woodacre1, J. A. Brown1,

School of Biomedical Engineering, Halifax, Canada

An endoscopic device that combines therapeutic ultrasound and imaging capabilities would be extremely valuable to minimally invasive surgical procedures, especially keyhole neurosurgery which requires a high level of precision. The small aperture makes it challenging to generate the peak pressures required for therapeutic techniques, particularly intrinsic histotripsy. Previously, a 5 mm by 5 mm histotripsy transducer was developed using PZT composite bonded to an aluminum lens. This device couldn't produce the pressure required to intrinsically cavitate within tissue. We present a new endoscope design that incorporates a "pump" transducer for increased peak pressure capability, and an imaging element in front designed to have minimal attenuation to the therapy. Our novel design combines three different frequency transducers stacked together without affecting the device cross section. The thicknesses of the piezo and coupling layers were optimized using a COMSOL time domain FEM model and maximize the peak pressure of the therapeutic pulse. The imaging transducer was a laser etched single 40 μm wide element representative of a previously described 64-element imaging array. A KLM model was used to evaluate the backing layers' effect on the imaging transducer output pulse. The therapy transducer with backing layers produced a pressure equivalent to an air-backed composite. Simultaneously pulsing the pump transducer increased the overall peak negative pressure. Adding the imaging transducer with coupling layer reduced the therapy signal by 4 dB, as predicted by the FEM model. This compares to a 9 dB loss in pressure without optimized coupling layers.

Investigating the Origin of the Frequency Dependence of Respiratory Resistance to Airflow in Disease – Application to Lung Transplant.

Anas Tahir[1], Alex Brezovan[1], Paul Hernandez[2], Andrew Ross[2], and Geoffrey Maksym[1]

[1]School of BME, Dalhousie Uni., [2]QEII Health Sciences Centre & Dalhousie Uni., Halifax, NS, Canada

Most lung disease affects the small airways first leading to heterogeneity in airflow where unfortunately the current clinical standard spirometry is ineffective. Oscillometry using small pressure oscillations is thought to be sensitive to heterogeneity via the frequency dependence of resistance to airflow (ΔR). Recently our lab showed that ΔR theoretically arises also from time-varying lung stiffness during oscillometry. Here we studied patients post lung transplant, who are at risk of chronic lung rejection - a small airways disease. We used SPECT/CT for ventilation heterogeneity and oscillometry for ΔR. In parallel, we are developing a computational model for lung tissue mechanics assessing the potential contribution from time varying lung stiffness.

METHODS/DISCUSSION: We measured eight subjects obtaining SPECT/CT, ΔR and another measure, the reactance X, which reflects lung stiffness. Interestingly, the subject with the greatest heterogeneity had negligible ΔR but large reactance (530% predicted) and ΔR was not correlated with heterogeneity across subjects. Additionally, the coefficient of variation used to assess SPECT/CT heterogeneity from all subjects was well corelated with reactance ($r2 = 0.8x$ $p < 0.01$) better than with spirometry. We are examining if the subjects show time varying elastance despite lack of ΔR.

CONCLUSIONS: Surprisingly, despite striking heterogeneity, ΔR was not increased, perhaps indicating that the frequency range was insensitive to the observed heterogeneity. Similarly, time varying elastic behavior was modest. While imaging and oscillometry were more sensitive to changes in lung function compared with spirometry, further modelling is needed to understand the lack of the predicted association with ΔR.