Proceedings

35th Great Lakes Biomedical Conference

Frontiers in Medical Imaging

FRIDAY, APRIL 12, 2013
GE Healthcare Institute
Waukesha, Wisconsin
# Conference Agenda:

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Each presentation will include 5-10 minutes for discussion and Q&A
Presenter Abstracts

Mike Barber  
*Chief Engineer, GE Officer*  
*GE Healthcare*

**Keynote Address**

Taly Gilat-Schmidt, Ph.D.  
*Assistant Professor, Department of Biomedical Engineering*  
*Marquette University*

**Title:** Spectral CT: Adding a New Dimension to CT Imaging

New x-ray detectors capture information about the energy of detected photons. This detected spectral information can be used to differentiate materials based on composition, which has shown promise for improved contrast-agent imaging. The spectral information can also improve the quality of conventional CT images. However, energy-resolving detectors are currently limited by effects such as pulse-pileup and nonideal spectral response. This talk will review material decomposition and optimal energy weighting methods for spectral CT data, including recent studies using k-edge nanoparticle contrast agents. This talk will also present novel methods of region-of-interest imaging to reduce pulse-pileup effects and an experimental investigation of optimal energy weighting using a bench-top spectral CT system.

Carl R. Crawford, Ph.D.  
*President*  
*Csuptwo, LLC*

**Title:** Explosive Detection for Aviation Security Using Technology from Medical Imaging

The events of 9/11 have demonstrated the increased need to detect terrorists and their threats. The threats include nuclear, biological and explosives targeted at infrastructure and transportation. The threats may be delivered in cargo, in luggage and by suicide bombers. Many different types of equipment have been deployed to detect these threats. The topics of this presentation include reviews of the threats and the detection technologies, and a discussion of the issues related to the deployment of these technologies. The talk will emphasize technologies that have been derived from medical imaging for detecting explosives targeted at aviation security. Carl Crawford is president of Csuptwo, LLC, a technology development and consulting company in the fields of medical imaging and Homeland Security. He has been a technical innovator in the fields of medical and industrial imaging for more than 25 years. Additional details can be found at [www.csuptwo.com](http://www.csuptwo.com).
**Walter Bialkowski, M.S.**  
*Senior Research Coordinator*  
*BloodCenter of Wisconsin*

Title:  Imaging Bone Density of Individuals Undergoing Regular Apheresis

Walter Bialkowski is a senior research coordinator at BloodCenter of Wisconsin. He is involved in the NHLBI-sponsored Recipient Epidemiology and Donor Evaluation Study-III (REDS-III) program that aims to improve blood component safety and availability in the United States. Within REDS-III he has been a leader in the development of the CABLE study that will assess the impact of repeated apheresis blood donation on bone mineral density. The anticoagulant citrate is administered during apheresis blood collection procedures. Exposure to citrate triggers changes in ionized serum calcium, parathyroid hormone, and markers of bone metabolism suggesting that alterations in bone density may occur. As part of the Recipient Epidemiology and Donor Evaluation Study-III (REDS-III), researchers have designed a multi-center clinical study to determine if repeated exposure to citrate affects the bone density of regular apheresis blood donors. This presentation will first introduce listeners to apheresis blood donation in contrast to other blood collection procedures and then explain the underlying physiology of citrate exposure. Bone density in blood donors will be assessed in this study using dual energy x-ray absorptiometry, a mature imaging modality that has gained renewed interest because of its role in predicting fractures.

**Peter Boesen**  
*Marketing Manager*  
*GE Healthcare*

Title:  Vscan: The Pocket Ultrasound That Helps Redefine the Physical Exam

The growth of personal digital devices with enormous processing power has enabled developers of medical devices to harness this power and create smaller, highly portable devices. This discussion explores the developments which enabled the of the Vscan hand held portable ultrasound and what influenced the industrial design. We will also explore what problems are solved and what problems are created by the development of disruptive technology in an effort to improve cost, quality and access in providing healthcare across the globe.
Ramin Pashaie, Ph.D.
Assistant Professor, Electrical Engineering Department
University of Wisconsin-Milwaukee

Title: Optical Interrogation of Large Scale Biological Neural Networks Via Optogenetics

Traditionally, neuropsychiatric disorders have been treated based on the chemical imbalance paradigm, which assumes that any mental disorder is caused by some abnormality in the concentration of chemicals. However, there is tremendous interest in going beyond the chemical imbalance paradigm and treating mental diseases by speaking the electrical language of neurons, the so-called interventional psychiatry. Deep-brain and transcranial magnetic stimulation are examples of this approach, in which cellular signaling is manipulated in neural subpopulations to alter network’s collective responses. Despite some exciting results reported, most interventional therapeutic procedures lack specific cell-type targeting strategies and potentially cause serious side effects. There is significant evidence that specific cell-types play crucial roles in several mental disorders. In a very promising approach known as optogenetics, a family of light-gated microbial opsins are developed that function as selective cation channels, and anion pumps, which are expressed in genetically targeted neurons. Once expressed in a neuron, the activity of the cell can be increased or suppressed, with millisecond temporal accuracy, by exposing the cell to light with appropriate wavelengths. Optogenetics has provided a remarkably powerful tool to investigate brain dynamics and communicate with its biological neural networks. Our research is focused on development of new technologies and implementation of novel optoelectronic instrumentation to optically modulate and monitor brain dynamics. During this presentation, I demonstrate some of our current projects including the single optical fiber probe developed for optogenetics, implementation of high precision microprojection and imaging device for optical programming of large scale networks in the brain, combining optogenetics with other medical imaging modalities such as fMRI, and development of optoelectronic neuroprosthetic devices.

Kevin Eliceiri
Director, Laboratory for Optical and Computational Instrumentation
University of Wisconsin-Madison

Title: Biophotonics: Convergence of Light and Biomedical Application

Revolutionary advances in biological and biomedical imaging over the last twenty years have brought about the development of improved methods for non-invasively imaging dynamic biological processes. Of particular significance have been optical techniques that have allowed for the visualization and manipulation of molecular and cellular structures within living tissue with minimal perturbation. The importance of these approaches has led to the development of a new field, Biophotonics, the study of photon interaction with biological materials. Biophotonics encompasses many research areas including probe development, optical instrumentation and data visualization. Biophotonics has quickly emerged as a multidisciplinary field of great importance to a diverse array of disciplines including chemistry, cell biology, computer science, biomedical engineering, and physics. A fertile area of biophotonics research and development is in the area of optical instrumentation where collaborative efforts are needed to develop the next generation of optical instrumentation and computational approaches for visualizing and assaying key biological and biomedical phenomena.
Career Planning Panel Session

Moderator:

Lisa Waples
BME Consultant
SRS LLC

Panelists:

Guy Berst
Associate Director of Recruitment and Development, Graduate School
Medical College of Wisconsin

Dave Curtis, CSTE
Senior Systems Test Engineer, Wells Fargo Funds Management Group
President, Milwaukee SPIN

Karen Johnsen
EEDP Program Manager
GE Healthcare

Marija Gajdardziska-Josifovska, Ph.D.
Associate Dean for Natural and Biomedical Sciences and Engineering
University of Wisconsin-Milwaukee

Maya Zelazo
Supervisor
Astronautics Corporation of America
Undergraduate Student Poster Abstracts
Adaptive Optics (AO) Retinal Imaging is an emerging imaging modality that is used to analyze the structure and density of the human retina. This modality is used to diagnose and study the structure of abnormalities in the retina including, but not limited to, macular degeneration and inherited blindness. In order to meet the growing demand for a higher resolution retinal imaging device as well as the ability to image rods and cones in the retina, the Medical College of Wisconsin, in association with the Eye Institute of Wisconsin, has developed a higher resolution device than what is currently used by clinicians. With this technology, retinal changes can be tracked over shorter periods of time. To provide repeatability for the system, a new automated digital fixation system was designed to replace the manual fixation system within the current AO device. The new system will help guide patients’ eyes while they are being imaged with the device and will allow for the captured retinal images to be correlated to the physical location in the retina that is being imaged. This is important for performing reliable analysis and descriptive statistics of the retina from the AO image and for automating the image processing, thus reducing processing time. Furthermore, by using an electronically adjustable lens and a graphical user interface, the fixation system can be adjusted to meet the vision needs of the patient being imaged by bringing the fixation point of the system into focus. Overall, the designed fixation system will bring the AO system closer to gaining approval from the Food and Drug Administration (FDA) for clinical research trials so the technology can become more widely adopted.
Therapeutic Hypothermia Cooling Device and Patient Monitoring System

Katelyn Herrmann, Lindsey Youngs, Kyle Ewert, Jeffrey Sugar

Milwaukee School of Engineering, Milwaukee, WI

Therapeutic hypothermia, or the controlled reduction of core body temperature to 32-34°C for an extended period, has been proven to increase the survival rate of patients who have experienced temporary loss of circulation, or ischemia. Conditions which lead to ischemia include, but are not limited to, sudden cardiac arrest, traumatic brain injury, and stroke. Although recently advocated as an important lifesaving procedure by the American Heart Association (AHA), therapeutic hypothermia is often underused due to lack of efficient resources, difficulties with current methods, and high costs. There are many current methods to induce hypothermia, and competitive products exist on the market; however, these are inefficient and often pose elevated risk to the patient. Therefore, the goal of this project is to design a system to more quickly, efficiently, and safely induce hypothermia in patients. To accomplish this, this design will combine two current methods to induce hypothermia – intravenous (IV) injection of cooled saline solution and surface cooling. The IV method is intended to be used primarily to provide an initial, rapid decrease in patient temperature, while surface cooling via a cooling blanket is intended to maintain target temperature for the duration of therapy. These components are integrated by a central control unit and user interface, which functions to continuously monitor patient core temperature to safely automate induction of therapeutic hypothermia.

Important specifications of the design include:

- Function to cool patient to 32-34°C (per AHA guidelines) within 2 hours
- Contain a device to cool a standard IV bag to 4-6°C within 20 minutes
- Contain an infusion system using a roller pump controlled to deliver cooled saline via a bolus or slower delivery rate, based on patient cooling needs
- Contain a standard cooling blanket to help cool and maintain patient at target temperature
- Contain a control unit to continuously monitor and display patient temperature, and adjust the flow rate or temperature of the IV solution, and the temperature of the cooling blanket to safely record and automate therapy

Thus far, an IV bag cooling device has been prototyped which is capable of cooling a 1.0L IV bag to 4°C in 15 minutes, meeting specification. This device functions to cool the IV bag using simple heat transfer via peltier plates and heat sinks. Currently, progress is being made to complete the design of the IV infusion subsystem and central control unit. The cooling blanket will a theoretical portion of this prototype. Testing will be done to ensure specifications of all subsystems are met, and theoretical calculations simulating the effects of the cooling blanket will be performed to evaluate system performance.
Android Fall Alert

Brandon Tomlin, Nora Huang, Winston Douglas, Keith Westpfahl, Kata Krzysztof

Milwaukee School of Engineering

According to the Center for Disease Control (CDC), 1 in 3 adults age 65 or older fall every year. Several products on the market try to address this issue, but lack the ability to offer an inexpensive and efficient way to communicate a fall at any location. Our team is addressing this issue by creating an automatic fall detection monitor that transmits the fall detection to an Android application. The application will then automatically alert a list of emergency number inputs, through a text message. Our three primary objectives for this product are as follows: make fall detection and transmission automatic, make a Smartphone application to automatically alert emergency contacts, and incorporate GPS location detection in the notification to allow for use of product outside the home. These objectives were made based on what is currently in the market and the needs of the potential customers. We have found that there is a growing market for a device like this. We are implementing these goals by integrating a fall detection algorithm into an Inertial Measurement Unit (IMU), which when a fall is detected, will activate an alarm and activate an Android application via Bluetooth. The application will then gather the location of the user using GPS and then text an alert to a predetermined list of emergency contacts. The fall detection algorithm was determined, based on a biomechanics study conducted by the design team. The final product will offer unprecedented protection and independence to its users.
Peripheral Neuropathy Assessment System

Ashley Brown, Brandan Fajardo, Michael Robertson, Christa Staudy, Kevin Zimmerman

Milwaukee School of Engineering

Peripheral neuropathy is a very slow progressing disease that damages the peripheral nervous system. The peripheral nervous system is the nervous system that connects the limbs and extremities to the brain and spinal cord. Peripheral neuropathy occurs most often due to damage of the nerve axons which can produce various symptoms. Commonly it presents as numbness and pain in the limbs and extremities, especially the feet. The nerve damage can result from various sources such as traumatic injuries, infections, and metabolic problems, but the most common causes are alcohol abuse and diabetes.

There is no cure for peripheral neuropathy, only treatments to alleviate the symptoms. The treatments determined for each patient are based on the diagnosis of how severe the patient’s neuropathy is. The severity of the patient’s neuropathy is determined by a doctor using diagnostic tests such as the light touch sensation test and the thermal discrimination test. These tests are used to diagnose the disease and track its progression in the patient. Currently, even when using both of these tests in combination, the diagnosis is still qualitative, subjective, and inconsistent. This is problematic because the diagnosis and tracking of the severity of a disease in a patient are used to determine what treatment would best aid the patient in dealing with this disease during their lifetime.

There are various devices on the market which are made specifically for the diagnosis of peripheral neuropathy, but none of them reduce the ambiguity and subjectivity from the physician. The scope of our device includes creating a system to assess a patient’s level of sensation that is known to decline with Peripheral Neuropathy in a standardized and quantitative approach. The device will test a patient’s touch sensation, or ability to perceive force, at the foot by using a stream of air that increases in speed until the patient can detect the air flow. The device will also test a patient’s ability to perceive temperature differences at the foot by using a two point thermal test that will increase until the patient can discern a difference in temperature between the two points. Both of these tests will be completely automated and standardized, taking out any subjective aliasing the physician may present in the results. This will allow for optimal tracking of the progression of Peripheral Neuropathy in a patient, and can lead to better treatment to alleviate the symptoms.
Our group has chosen to focus our efforts on the rehabilitation of sports related injuries to the knee. In this regard, we are improving upon various feature of a Continuous Passive Motion device (CPM). Currently, physical therapists are having issues with compliance for the designated at home rehabilitation assignments. Therefore, our team is looking to incorporate a patient monitoring system into the device. This monitoring system would include data such as usage time, total angle of bend achieved, a graph of the angle of bend vs. time and a normalized torque reading of the knee joint as a ratio to the stiffness of the patient’s healthy knee. This project will, therefore, incorporate quantitative specifications while still evaluating the issue of compliance. Our team looks to interface our CPM device with a microcontroller to record data pertaining to the users rehab session. This data will then be extracted to a graphical user interface (GUI) to simultaneously display the patient’s progress in comparison to the baseline measure of their healthy knee on a laptop screen. Additionally, within this GUI the physical therapist will be able to set the baseline, the patient’s progress will be saved and then transferred directly to a physical therapist via email in an easy to read report of the therapy session.
At Home Neonatal Seizure Monitoring System

Holly Eggleton, Josiah Simeth, Matthew Cornish, Ashley Gray

Milwaukee School of Engineering

This project involves the creation of an at home neonatal seizure monitoring system with automated feature detection software designed to aid in the detection of seizures. By detecting these seizures in the home a physician may intelligently wean the neonate off of potentially harmful anticonvulsant medications, without frequent or long term monitoring in the hospital. This could potentially reduce costs while giving physicians further resources for quantitatively assessing the effectiveness of anticonvulsant medications on neonates. Created EEG and ECG circuitry will be used to detect signals used as indicators of seizure events. All data will be stored on the home PC where further development could allow it to be uploaded to an online database the doctor could access and analyze with the designed MATLAB graphical user interface (GUI).

This system aims to do the following:

• Collect EEG and ECG data with the device
• Transfer digital EEG and ECG signals to a laptop PC via Bluetooth
• Analyze the signals for several features related to seizure activity in neonates, including spectral entropy, dominant spectral peak, and RMS amplitude
• Provide a useful GUI for easy data review by a physician

This block diagram depicts the basic operation of the system being designed. The design and construction will be completed by the end of May 2013.
INTRODUCTION: There are many jobs that require a worker to kneel for a prolonged period of time which can be physically demanding. The response of the knee flexors and extensors during kneeling was previously investigated only through electromyography. We hypothesized that by flexing the knee and applying pressure the blood flow will be suspended to the supporting muscles and stretch the passive tissue such as ligaments. Therefore, the first aim of this pilot study was to measure and quantify the changes in muscle oxygenation during a prolonged kneeling task. The second aim was to examine the time required for muscle oxygenation to return to the baseline state by quantifying the changes in level of oxygenation during the recovery period.

METHODS: Four student volunteers, three males and one female, participated in this pilot study. The subjects were asked to kneel on both knees, in a 90° flexion posture for 15 minutes, with a kneeling mat. Muscle oxygenation levels were continuously measured using two Near Infrared Spectroscopy (NIRS) sensors (Nonin Medical) positioned on the Rectus Femoris (RF) and Bicep Femoris (BF) muscles. The baseline values at the beginning of the trial, as well as the changes in oxygenation level during kneeling and recovery were recorded. The range of motion (ROM) of the knee joint was obtained using a Biodex 4 Pro System before kneeling to establish the baseline, and at the end of the experiment to monitor recovery.

RESULTS: A steep and steady drop in muscle oxygenation was observed during kneeling, with rSO2 levels dropping 11.4% compared to baseline after 15 minutes of kneeling for both the BF and RF. Very little recovery in muscle oxygenation was observed for approximately 10 minutes after the end of kneeling. Full recovery of oxygenation was observed after 15 minutes for the RF, while the BF still exhibited a 5.7% decrease in oxygenation. In order to check if muscle oxygenation is indicative of recovery of other biomechanical markers, the knee ROM was measured before kneeling and after 15 minutes of recovery time. After 15 minutes, ROM for the knee showed a 2.2% increase from the baseline condition.

DISCUSSION: Three observations may be made based on the results. First, kneeling directly affects upper leg muscle oxygenation with a large decrease seen very quickly, and no lessening of the downward trend over a 15 minute kneeling period. Second, recovery of oxygenation levels did not begin until 10 minutes into the recovery period, and full recovery took at least 15 minutes or longer, suggesting that longer recovery periods are required than the one to two minutes commonly recommended as breaks during prolonged kneeling. Third, muscle oxygenation recovery and ROM recovery did not occur at the same pace. At the time when oxygenation had fully recovered, increased ROM was still found, indicating that stretching of the ligaments may have occurred during prolonged kneeling and had not yet fully recovered. In conclusion, the results of this study suggest that prolonged break periods are required during kneeling, and that recovery of one biomechanical marker does not indicate recovery of other measures. In addition, the use of NIRS muscle oxygenation measurement as a biomechanical marker has considerable promise and future research should consider oxygenation in addition to other measurements.
Ex Vivo Thermoacoustic Imaging of Prostate Cancer

Stephanie Griep Majorca Thomas

University of Wisconsin, Milwaukee Department of Physics

The central question for this research project is, “Can thermoacoustic imaging detect prostate cancer?” The purpose of this project is to develop a way to image prostate cancer that current medical imaging technology fails to visualize. We perform ex vivo imaging in thermoacoustic computed tomography (TCT) testbeds of fresh prostates that have been removed due to cancer. Fresh surgical specimens are picked up from the hospital immediately after surgery and transported directly to the University of Wisconsin, Milwaukee campus for scanning. After scanning, the specimens are returned to the histology department for analysis.

Two ultrasound transducers receive signals generated by the thermoacoustic contrast mechanism generated by high power, sub-microsecond very high frequency (VHF) electromagnetic pulses. Specimens are imaged in step-and-shoot mode, with 3 mm translation between slices. The ultrasound transducers are positioned 180 degrees apart and we typically rotate the specimen only 252 degrees per slice to reduce data acquisition time. The VHF performance of the system is monitored during specimen scanning. A LABVIEW code is used to drive electromagnetic hardware, the stepper motor, and to acquire data.

The raw sinograms acquired are first corrected and then reconstructed using MATLAB to produce a stack of images. During data correction, electromagnetic interference is manually removed from the raw sinograms, as it is consistent from view to view. Multiple reflections between the tissue and the glycine solution are also manually removed from raw sinograms to make the final image easier to view. Data from each of the transducers is then combined to generate a full 360 degree sinogram. Once filtered, the sinograms are reconstructed by filtered back-projection.

To test system performance, straws filled with physiological buffered saline have been imaged and demonstrate 3 mm in-plane resolution. Unfortunately the slice-sensitivity profile generated by imaging small washers had FWHM of approximately 1 cm. Also, while scanning one of our first prostates, we inadvertently left a staple on it and it appears as streak artifacts as seen in the image below.
Effects of Foot Placement and Foot Kinematics on Ladder Slip Events

Erika Pliner, Kurt Beschorner, Ph.D., and Naira Campbell-Kyureghyan, Ph.D.

University of Wisconsin-Milwaukee, WI, USA

Ladder-related falls are the leading cause of disabling falls to lower levels [1]. Rung shape, orientation, and friction are important factors in generating hand forces and assembly for a safe ladder design [2]. However ladder climbing is a full body activity and few studies have considered the role of the lower-body during slipping. Understanding the effects of climbing technique on ladder slip/fall risk is critical to training safe ladder climbing. This study investigates the effects of foot placement on frequency of ladder slips and falls and the kinematic variables involved with slip outcome.

The study included 32 participants aged 18-65 with 10 females. Forty-six reflective markers were placed on anatomical landmarks of the participant and were tracked during each trial (100 Hz). Participants climbed a vertical 12-foot ladder equipped with five reflective markers. Lockable bearings were applied to the fourth rung so that it locked during non-slip trials and spun during slip trials. A safety harness was equipped with a load cell to determine the participant’s weight supported by the harness (1000 Hz).

Each participant was randomly assigned to two of four climbing strategy groups varying in hand positions (rungs or rails) and foot placements (mid-foot or forefoot). Participants were allowed to acclimate to the ladder prior to data collection. For both climbing strategies, participants climbed the ladder 5-8 times with the rung locked in place and then once when the rung could freely spin. The climber’s safety was ensured throughout the testing session with a belayer, spotter, and an impact mat. A trial was classified as a slip if the participant’s foot completely slipped off the perturbed rung and as a fall if the load in the harness supported more than 10% of the participant’s body weight. For each slip event, the ascent and descent were considered to be separate samples. ANOVA analyses were used for statistics.

Participants slipped off of the rung 16 times and fell five times during the 64 slip trials. Slipping was seven times more likely with forefoot than mid-foot placement (p<0.01) and falls occurred exclusively with the forefoot placement (p<0.01). From foot contact to contralateral foot-off, the foot moved posteriorly during the forefoot climbing and anteriorly during mid-foot climbing (p<0.01). The forefoot also moved more posterior during slipping trials compared with non-slipping trials (p<0.001). Climbing on the forefoot led to smaller foot angles at foot contact (p<0.05) and at contralateral foot-off (p<0.001). A larger increase in foot angle between foot contact and contralateral foot-off occurred among participants who slipped compared with participants who did not slip (p<0.05).

This work was funded by University of Illinois-Chicago/NIOSH/CDC (5T42OH008672-08)
Shoe-Floor Friction as a Hard Surface/Rubber System

M Cowap¹, K Beschorner²

University of Wisconsin-Milwaukee, WI, USA

Motivation: Extensive research has been performed on the friction between rubber and hard contact surfaces [1]. However, there has not been as much effort to apply these findings to the reduction of slips in shoe-floor interactions. More than 50% of occupational falls can be attributed to slips [2]. This research investigated the effects of shoe material, speed, floor roughness, and liquid contaminants on the relative contributions of adhesion and hysteresis to the overall coefficient of friction in a rubber against a hard surface system.

Method: Experiments were conducted using a pin-on-disk tribometer. Two types of shoe material were used, Neolite and a soft rubber. Neolite is a standard material in shoe-floor friction testing and the soft rubber came from a common type of work shoe. Ceramic tiles were sandblasted at an inlet pressure of 345 kPa for 1 & 5 minutes and at an inlet pressure of 860 kPa for 5 minutes to reach three levels of roughness, measured as the average peak-to-valley height (Rz). The measured roughness levels were 16.575 µm, 24.263 µm, and 35.107 µm, respectively. Five liquid contaminants were used: diluted glycerol (25%, 50%, and 75% glycerol), canola oil, and SAE75W140 gear oil. These contaminants were chosen because the viscosity of glycerol is easily controlled, canola oil is a common hazard in the food industry, and gear oil blocks most adhesional friction, allowing the effects of hysteresis to be isolated. The shoe samples were slid over the tiles at six speeds, from 0.01 m sec⁻¹ to 1.0 m sec⁻¹. Six trials of each combination were collected and the average recorded as the coefficient of friction for that combination.

Adhesional friction was calculated with the following equation:

\[
\text{CoF}_{\text{Adhesion}} = \text{CoF}_{\text{Overall}} - \text{CoF}_{\text{Hysteresis}}
\]

where \(\text{CoF}_{\text{Hysteresis}} = \text{CoF}_{\text{Gear Oil}}\)

An ANOVA was done on the results to determine which factors had an effect on the coefficient of friction.

Results: The overall coefficient of friction was positively correlated with floor roughness. It was negatively correlated with sliding speed, contaminant viscosity, and shoe material hardness. Adhesional friction was strongly negatively correlated with sliding speed and contaminant viscosity. It was positively correlated with shoe material hardness. Hysteretic friction was negatively correlated with sliding speed and shoe material hardness. It was positively correlated with floor roughness.

Conclusions: The results indicate that hysteresis becomes more important to the overall coefficient of friction if the sliding speed is high and in the presence of liquid contaminants. When a hard surface is coated with a liquid contaminant, adhesion between the surface and the shoe material tends to be less reliable. However, hysteresis remains relatively constant in the presence of such a contaminant. This suggests that taking steps to increase hysteresis between a shoe material and the floor surface could reduce the number of slips that occur in a workplace.
Graduate Student Poster Abstracts
Monoplane Stereoscopic Imaging Method for Inverse Geometry X-ray Fluoroscopy

Michael T. Tomkowiak\textsuperscript{a}, Michael S. Van Lysel\textsuperscript{b,c}, Tobias Funk\textsuperscript{d}, and Michael A. Speidel\textsuperscript{b,c}

\textsuperscript{a}Dept. of Biomedical Engineering, \textsuperscript{b}Dept. of Medical Physics, and \textsuperscript{c}Dept. of Medicine, University of Wisconsin, Madison, WI; \textsuperscript{d}Triple Ring Technologies, Newark, CA

Background: X-ray fluoroscopy (XRF) is the primary image guidance tool for deploying wires, catheters, and other devices during cardiovascular interventions due to its high spatial and temporal resolution and ease of use. However the x-ray projection process compresses all of the features in the 3D imaging volume into a single 2D image, eliminating information about device depth and orientation. Stereoscopic XRF imaging can be used to recover depth information from XRF projections, but implementations with conventional XRF gantries use sub-optimal bi-plane geometries or asynchronous acquisition of the two views. We present a novel method for generating stereoscopic XRF images using an inverse geometry XRF system, which reconstructs the two x-ray views from a single dataset acquired at a single gantry angle and which offers flexibility in the relative geometry between the two views for visualizing depth and orientation of anatomical features and devices.

Methods: The Scanning Beam Digital X-ray (SBDX) is a low-dose inverse geometry fluoroscopic system for cardiac interventional procedures. For each frame period (15-30 fps), SBDX performs digital x-ray tomosynthesis at multiple planes within the patient volume, and the in-plane features from the tomosynthetic images at each plane are combined into a composite image for fluoroscopic display. These “virtual projections” have geometric properties similar to conventional x-ray projections and can be adjusted by reconstruction parameters. Using the raw scan data from two different regions of the detector, two slightly offset virtual projections can be created to form a stereoscopic image pair. To verify the geometry of the stereoscopic images, a phantom containing steel spheres in a known arrangement was imaged. The geometry of the spheres was reconstructed using a previously described stereoscopic 3D localization method and compared to the known phantom geometry. To assess whether device orientation could be determined from the stereoscopic images, a cardiac radiofrequency (RF) ablation catheter was imaged at orientations towards and against the projection direction. The stereoscopic images were rendered as red/cyan anaglyphs and compared to standard reconstructions to determine if device orientation could be resolved with the stereoscopic images.

Results: From the stereoscopic images, the phantom geometry was reconstructed and registered to the known geometry using a point based rigid transform. The 3D residual RMS errors were between 0.81 and 1.93 mm, depending on the parameters used in the stereoscopic reconstruction, with the greatest error components along the depth direction. Stereoscopic images of the cardiac ablation catheter were generated using the proposed method, and when viewed as a stereoscopic anaglyph, the true catheter orientation (towards vs. away) could be resolved.
Multi-scale analysis of collagen architecture for classifying tumor and healthy breast tissue images

Departments Cell and Molecular Biology and Biomedical Engineering, Morgridge Institute for Research - University of Wisconsin - Madison, WI 53706

Introduction: There is growing evidence that collagen architecture plays an important role in cancer metastasis. In order to measure the influence of collagen on cancer or cancer on collagen, we need robust methods for imaging and quantifying collagen architecture. In this study, we address this need with an innovative combination of imaging and signal processing. Extended field of view second harmonic generation (EFOV SHG) microscopy helps prevent sampling bias while analysis with the curvelet transform provides unique image features that are well suited to patterns observed in the collagen images. Our purpose here is to quantify differences in collagen microarchitecture between healthy human breast tissue and breast cancer images using EFOV SHG microscopy coupled with analysis by the curvelet transform.

Methods: Two frozen samples of normal associated human breast tissue (NAT) and invasive ductal carcinoma (IDC) were obtained through the University of Wisconsin BioBank. Samples were thawed, fixed, embedded in agar, cut into 300 micron thick sections using a vibratome and imaged using a custom inverted SHG microscope designed to allow for EFOV imaging. Individual SHG Images were captured at 0.79 micron resolution and a FOV of approximately 200 microns. The FOV was extended by stage scanning and image stitching to produce submicron resolution fields of view up to 2 cm². NAT and IDC tissues were imaged, stitched using the Grid/Collection Stitching ImageJ plugin, and analyzed using features derived from the curvelet transform including variance in orientation and prevalence at various scales. These novel features were tested using support vector machine (SVM) cross validation.

Results: Representative collagen architecture images of IDC and NAT are shown in figure 1. IDC tissue contained linearly aligned, crisscrossing collagen while NAT tissue contained wavy, dense collagen. These images were produced by stitching together 121 small fields of view each approximately 200 µm². We separate the large images into 512X512 pixel patches and perform the curvelet transform on each patch, producing 81 independent observations per class. We use a support vector machine (SVM) to evaluate the efficiency of two novel features. The first feature uses the number of coefficients at the second finest curvelet scale and the second feature uses the variance of orientations at the second finest scale. This scale is selected based on an analysis of features at all scales. The second finest scale is the most informative for our magnification. The result of the two dimensional SVM analysis shows NAT features clustered in the upper left of the graph, while IDC features clustered in the lower right of the graph, demonstrating the classification ability of our proposed features. The mean curvelet alignment value for the normal images was approximately 2X higher than that for IDC. In addition, normal images had approximately 20% fewer closely correlated curvelets compared to IDC. Three-fold cross validation of a linear SVM classifier revealed average sensitivity and specificity of these features to be 0.994 and 0.969 respectively.
BIPLANE FLUOROSCOPIC ANALYSIS OF THE HINDFOOT: 
A STATIC PHANTOM STUDY

Janelle A. Cross, Ben McHenry, Gerald F. Harris, and Taly Gilat Schmidt

Biomedical Engineering Dept. – Marquette University – Milwaukee, WI

Conventional motion analysis using skin-mounted markers to track the motion of underlying bones has been found to suffer from error due to movement of the skin where the markers are placed [1]. Due to the numerous bones and articulating surfaces within the foot and ankle, several rigid body assumptions are made to divide the foot into multiple segments for motion analysis. This method does not allow for obtaining inter-tarsal kinematics or kinetics of the hindfoot. Fluoroscopy offers a valuable complement to conventional motion analysis by providing dynamic weight-bearing intra-articular motion measurements that are otherwise difficult to achieve. Our group has previously reported hindfoot kinematics obtained from a single gantry [2]. Model-based fluoroscopy identifies bony position and orientation by comparing a three dimensional (3D) bone model to acquired biplane fluoroscopic images. The 3D model is created from computed tomography (CT) or magnetic resonance (MR) images by identifying and segmenting the anatomy of interest. The accuracy of the model-based method was found to be within 0.8 mm of translation and 2.5° of rotation of the gold standard measurements performed with implanted bony markers [3]. The goal of this study was to develop a unique biplanar system that uses model-based tracking methods to perform in vivo analysis of the hindfoot.

A biplane system was constructed centered along a raised walkway with an embedded force plate (AMTI OR6-500 6-DOF, Watertown, MA). Two x-ray sources (OEC 9000, GE, Fairfield, CT), and two images intensifiers (15" diam., Dunlee, Aurora, IL) were mounted to the walkway with a 60° angle between the sources. High-speed cameras (N4, IDT, Pasadena, CA) were attached to each image intensifier (II). Images were captured directly to a controller PC via Motion Studio 64 (Versión 2.10.05, IDT, Pasadena, CA). Source-to-detector and source-to-object-center distances were 112 cm and 76 cm, respectively. Open source software, X-Ray Reconstruction of Moving Morphology (XROMM, Brown University, Providence, RI) was used for II distortion correction. Calibration frames of 1.20 mm thick perforated steel with 3.18 mm diameter holes spaced 4.76 mm apart in a staggered pattern were cut to fit the face of the II (part no. 9255T641, McMaster-Carr, Robinson, NJ). An acrylic calibration cube as described by Brainerd et al. was manufactured with 64 steel spheres implanted as calibration points [4]. A CT scan was performed on a foot/ankle phantom (XA241L, Phantom Lab Inc). Static images were collected of the calibration cube, and then the foot phantom with the x-ray sources set at 100 kV and 2.5 mA, with an estimated 10 μSv of radiation per trial.

A unique biplane fluoroscopy system designed for hindfoot analysis was built, tested and approved through the State and medical IRB for subject testing. In order to quantify the cross-scatter contamination in the biplanar system, a study was performed [5]. Contamination was found to be relatively low when imaging distal extremities. Images of the calibration frames were corrected for geometric distortion using XROMM to create a transformation matrix.
Optogenetics is a recently developed technology that has the ability to both stimulate and suppress neural activity with light\(^1\). In addition spectral-domain optical coherence tomography (SD-OCT) is a non-invasive imaging technique that has been shown to rapidly image cortical microvasculature in-vivo\(^2\). The overall goal of the project is to create a closed loop paradigm that will both control and monitor neural activity in the brain. In this study a multimodal OCT system has been developed to monitor microvasculature activity which incorporates rapid hemodynamic, fluorescent and metabolic imaging. To provide initial proof of concept a specialized system has been designed, built and demonstrated the capability of high-speed non-invasive, in-vivo imaging of cortical microvasculature.

The OCT system was designed and tested to validate the implementation of in-vivo imaging of microvasculature in the brain. To test the capability of imaging microvasculature inside the cranium, onion cell bodies where imaged through a thin slice of bone with a resolution of 10 x 10 x 8 \(\mu\)m.

The system was optimized for real-time imaging monitor hemodynamic activity. The enhanced capability of the system can provide imaging rates of between 20 and 40 images (512x512 pixels) per second. This high-speed tool will allow for real-time microvasculature monitoring video rates. Additional fluorescent image modalities can coordinate auto-fluorescent metabolic signals with hemodynamic reactions.

Our OCT system has demonstrated the capability of in-vivo imaging in real time. Next Electrocorticography (ECoG) and optogenetics stimulation will be added to interrogate cortical microvasculature. Combined, this multimodal imaging system can demonstrate the correlation between temporal changes of blood velocity in brain superficial areas and neural activity recorded with ECoG.
Introduction: Jack-hammering is a very common task among construction workers and poses injury risk to the operator due to repetitive lifting and vibration. Additionally, with the common weight of jackhammer being 90lbs, limited populations have the ability to operate this equipment. According to the National Institute for Occupational Safety and Health most jackhammers exceed the recommended lifting limit. In order to reduce repetitive lifting during the jack-hammering task, a special jackhammer lift assist (LA) is designed to lift the jackhammer onto the pavement. However, to date there has been no study that has investigated and quantified the actual benefits of a LA.

Methods: Six experienced jackhammer operators were recruited for this study. Each operator mimicked working conditions by breaking a 3ft x 3ft concrete slab using a jackhammer with and without a LA. Operators wore a pressure sensing glove (FSA, Vista Medical) on their right hand to collect grip pressure. Average operating and peak lifting grip pressure were extracted from the recorded data. A Nexgen accelerometer was placed on the operator’s left hand to measure hand arm vibration which was analyzed using VATS vibration software. Two main phases of the task were identified: operating and lifting. The hand grip pressure data was analyzed using a custom MATLAB program. A paired t-tests were performed in Minitab to detect statistical differences at \( \alpha =0.05 \). All subjects signed an informed consent and the study was approved by the IRB.

Results: LA resulted in an overall 30% reduction in grip pressure during the lifting phase of the task. Reductions ranged from 20%-44% between operators. During the operating phase of the task smaller (12%) reductions in overall grip pressure were observed due to the LA. The differences in peak grip pressure during both phases due to the LA usage were found to be statistically significant (\( p<0.05 \)). Interestingly, the addition of the LA helped to reduce hand-arm vibration (HAV) by 11% on average during the operation phase of the task, but the difference was not statistically significant (\( p=0.053 \)). Four of the six operators had a decrease in total task time with the LA. The other two operators had trouble adjusting to the LA, and this could have caused the slower performance. This suggests that the jack-hammering task can become faster by using the LA after experience is gained.

Discussion: The decrease in peak lifting grip pressure from using the LA means a reduction in required lifting load that would benefit the operator by reducing the risk of overexertion injury. Therefore using a LA could possibly allow for a larger population to perform the jack-hammering task. A decrease in task time will reduce the overall workload of each individual jack-hammering task. It has been established that hand arm vibration increases proportionally to the cube root of hand contact force and that hand contact force is a function of grip and pushing forces. The LA did reduce grip pressure during operation. However, the reduction in grip pressure during operation did not lead to a significant decrease in HAV.
Computational Vibrational Removal of Femoral Implants

Michael Keenan¹, Matthew Squire², Jill Meyer¹

¹Orthopedic Biomechanics Laboratory, University of Wisconsin-Milwaukee
²Department of Orthopedics and Rehabilitation, UW Hospital and Clinics

Revision total hip arthroplasty (rTHA) is a surgical procedure required after the failure of a primary hip replacement surgery, due to numerous reasons including loosening and infection. With an increasing number of primary THAs performed each year, even with a decrease in failure rates, there has been a significant increase in rTHAs being performed. Conducting an rTHA is an arduous task where significant time, effort, and skill is devoted to removing the previously implanted device. To provide significant advantages over current surgical procedures, the current study proposes to utilize an implant’s natural frequency to debond the implant from its surrounding bone cement mantel. To provide initial proof of concept results to validate the concept, an extensive finite element (FE) model has been constructed.

Nine femoral implants were scanned using a Minolta vivid 910 non-contact 3D digitizer. Scanned surfaces were then stitched together to create 3D volumes using Geomagic Studio 12.0 (Geomagic, Research Triangle Park, NC). Once the implants were digitized, each implant was meshed using tetrahedral element in Abaqus V6.10-EF (Dassault Systems, Velizy, FR). Each implant’s natural frequency range was calculated based on geometry and materials using three boundary conditions and varying the material properties to common implant grade materials. The three boundary conditions included complete fixation of the full length of the femoral stem, 2/3 of the femoral stem, and 1/3 of the femoral stem (Figure 1).

Based on the natural frequencies derived, one implant was chosen for further demonstration of the design concept. This implant was digitally implanted into a bone cement block, where the cement mantel was approximately 2 to 5 mm thick, typical in THA. The implant and the cement block were meshed using linear tetrahedral elements with a seed size of 1 mm. The implant-cement interface was fully bonded and the implant was “vibrated” using a rotating dynamic load applied to the implant’s femoral neck, shown in pink in Figure 2. Loading was based on a 60g weight spinning at the natural frequency of the implant. A fixed boundary condition was applied on the anterior and posterior sides of the cement mantel. To determine the effectiveness of this technique as a novel surgical procedure, crack growth was simulated in Abaqus using the extended finite elements methods (XFEM) with a maximum principle stress damage criterion. Cracks were initialized using a small indentation at both the most medial and lateral points on the implant.

The simulation demonstrated continuous crack growth through the length of the cement mantel, providing initial proof of concept evidence for this novel surgical procedure. It has been demonstrated that by initiating a small crack at the most medial and lateral positions of a femoral implant, a vibrational force can cause significant cracking of the cement mantel. This provides the initial evidence that these methodologies could significantly reduce the time, effort, and expertise of removing an implant during rTHA.

Figure 1: The three boundary conditions used to find the range of natural frequencies for an implant. The red area represents the fixed boundary condition.
Hand function assessment of stroke patients using non-invasive surface near-infrared spectroscopy

Gregory Michalak*, Whitney Linz*, Mohammad Masoudi Motlagh†, Na Jin Seo‡, Mahsa Ranji**

†: Biophotonics Lab, EMS 885, ‡: Hand Rehabilitation Lab, USR 281
University of Wisconsin – Milwaukee, WI

Introduction: The oxygenation level of a tissue is an important marker of the health of the tissue. Sustained extreme oxygenation levels, in either direction, can cause irreparable damage. In stroke survivors, it has been shown that the blood flow to paretic limbs is significantly reduced compared to a non-paretic limb [1]. We hypothesize that hemodynamic activity in stroke affected muscles is suppressed as compared to normal muscles. In order to measure the hemodynamic activity, we developed a prototype optical sensor to measure the relative changes in the concentration of oxygenated and reduced hemoglobin (Hb and HbO$_2$) in the tissue using Beer's Law.

Objective: The objective of this study is to examine the difference in muscle blood volume and oxygenation changes in the paretic and non-paretic forearms of stroke patients in order to gain valuable information about the cardiovascular differences between normal and stroke affected limbs. Additionally, our optical technique may provide a useful tool for clinicians administering rehabilitative exercise protocols to stroke patients.

Methods: We will measure the change in blood volume and oxygenation in the flexor digitorum superficialis and extensor digitorum muscles in stroke survivors' paretic and non-paretic forearms. The stroke patients' data will also be compared to a control group of healthy individuals drawn from the general population. The optical probe, consisting of a three-wavelength LED source and four evenly spaced photodetectors, will be affixed to the subjects' arms using an elastic band. The forearm will be secured so that only the muscles in the region of interest are free to move. Each subject will undertake four trials, one in each muscle, consisting of three exercise levels calibrated to the subject's maximum effort. In post-processing, we will use the output intensity of light at each wavelength to calculate the changes in the relative concentrations of Hb and HbO$_2$ in the muscle.

Results: Preliminary results from our probe show a significant change in the blood volume and oxygenation in the muscles of healthy subjects between exercise and rest. We expect to see a huge difference in oxygenation signals of stroke patients. This study is still in progress.
MUSCLE CO-ACTIVATION DURING PROLONGED KNEELING

Daniel Lomo-Tettey¹, Blake Johnson¹, Naira Campbell-Kyureghyan², Kurt Beschorner, PhD²

Industrial and Manufacturing Engineering, UWM, Milwaukee, WI
¹Graduate Student; ²Faculty Advisor

INTRODUCTION
Many daily occupational tasks in construction, utilities, mining and other industries involve frequent and/or prolonged kneeling. Prolonged kneeling and squatting have been identified as major work-related risk factors that predicted new-onset low back pain and knee osteoarthritis [1, 2]. Medical treatment insurance claims for injury to the combined knee, lower back, and shoulder from eight mining companies in the US from 1996 to 2008 are over $9 million dollars [3]. Nevertheless, a gap in the literature exists regarding the biomechanical response to prolonged kneeling. This paper discusses leg and torso muscle response during prolonged kneeling on two legs at 90 degrees of knee flexion.

METHODS
Eight healthy subjects (age 20-50 years) volunteered and participated in the study (7 males, 1 female). The subjects knelt on both knees at 90 degrees of knee flexion on a kneeling mat placed over two identical force plates (AMTI, Watertown, MA) for up to 30 minutes. Electromyography (EMG) activity for twelve leg and torso muscles was recorded using 12 wireless surface electrodes (Delsys Inc, Boston, MA). The leg and torso muscles recorded were: Rectus Femoris (RF), Vastus Lateralis (VL), Vastus Medialis (VM), Semitendinosus (SEM), Biceps Femoris (BF), Tibialis Anterior (TA), Medial Gastroc (MG), Lateral Gastroc (LG), bilateral Rectus Abdominis (RA), and bilateral Erector Spinae (ES). EMG data was recorded at 2000Hz and filtered. Force plate data was collected at 1000Hz and filtered. EMG root mean square (RMS) amplitudes were computed with 0.125s window size and an overlap window of 0.0625s and then normalized to the first one minute of initial kneeling. ANOVA and post hoc Tukey pair-wise tests were used to determine statistical significance between muscle activation levels and kneeling time.

RESULTS AND DISCUSSION
The results show that SEM activity was higher at 5 minutes (22%) and 30 minutes (21%) than at 15 minutes (p=0.013 and p=0.026 respectively). Similarly, RA activity was 90% higher at 5 minutes than at 15 minutes (p=0.006) and 70% higher than at 30 minutes (p=0.046). The implication of this study suggests that kneeling on two legs at 90 degrees of knee flexion over 10-15 minutes starts changing muscle activation patterns, primarily in the knee and torso flexor muscle groups.

CONCLUSIONS
Changes in activation patterns were observed during prolonged kneeling. The hamstrings and abdominal muscles are the main stabilization muscles of the leg and torso. Most changes start occurring after 5-10 minutes of kneeling. Additional research is needed to determine the specific causes of these changes in activation patterns over time and how these changes might be related to tissue damage that causes kneeling-related disorders.

REFERENCES
Optical Redox Imaging to Monitor Metabolic Dysfunction in Polycystic Ovary Syndrome

Sepideh Maleki, Mohammad MasoudiMotlagh, Fariba Assadi-Porter, Mahsa Ranji*
Biophotonics lab, EMS 885 University of Wisconsin – Milwaukee, WI

Introduction: Polycystic Ovary Syndrome (PCOS) is a disorder characterized by cystic ovarian morphology, androgen excess, and ovulatory dysfunction, which is the most common endocrine disorder of women of reproductive age with a worldwide prevalence of 10%. In this study, a well-known prenatally glucocorticoid treated mouse (cort-mouse) model for “PCOS-like” symptoms is used that mimics biochemical dysfunction similar to those observed in lean PCOS women. The cryofluorescence imaging technique was used to quantitatively assess tissue metabolism and oxidative stress with age in cort-treated mice. The mitochondrial metabolic coenzymes NADH and FAD are autofluorescent and can be monitored without exogenous labels using optical techniques. More specifically, the ratio of the fluorescence intensity of these fluorophores (NADH/FAD), the NADH redox ratio (NADH RR), is a marker of the metabolic state of the tissue.

Objective: The objective of this study was to quantify the oxidative state of the kidney, ovary and heart in a rodent model of PCOS using an optical imaging technique at different stages of disease progression. We examined the NADH RR in the kidney, ovary and heart from 8 week (8W), 12 week (12W), and 16 week (16W) old wild-type (control) and cort-treated mice.

Method: NADH and FAD autofluorescent images from each group of kidney, ovary, and heart were processed to extract NADH RR values using MATLAB. Composite images were created using all the image slices for each tissue, for both NADH and FAD signals. On average, images were recorded from 400 cryo sections in the axial direction per organ. The stacks were analyzed in MATLAB to measure the 3-D maxprojection NADH RR of tissue and their histograms.

Results: Kidneys from cort-treated 8W, 12W, and 16W old mice showed a 50%, 17.5%, and 15% more oxidized respiratory chain compared to wild-type mice at the same age, respectively. The results in ovaries from cort-treated 8W, 12W, and 16W old-mice showed 22%, 30%, and 36% change in the mean NADH RR compared to wild-type mice at the same age, respectively. Finally, the results in hearts from cort-treated mice showed 35% change in the mean NADH RR compared to wild-type mice in all three ages.
INTRODUCTION: Gas utility workers routinely change the gas meters on residential and commercial buildings. These meters are mounted at a variety of heights and the fittings require a high amount of torque to turn. During this task many workers suffer injury to their shoulder, elbow, or hand. Reduction in the peak muscle activity or pressure on the worker’s hand could reduce the risk of injury. It is hypothesized that the grip pressure and muscle activity for the worker will be higher at increased shoulder abduction.

METHODS: Four healthy male subjects with little to no previous experience using a pipe wrench volunteered to participate in this pilot study. All subjects were asked to detach a gas meter from its pipe work by loosening two fittings and then to re-attach the gas meter by tightening the fittings to a set point using a standard 18 inch steel pipe wrench. The gas meter was mounted in the lab on adjustable rails to control the height of the meter. The heights to the fittings were set at 35” (Low), 53” (Middle), and at eye level of the subject (High). Grip pressure was measured using a 24 sensor pressure glove (FSA, Vista Medical) placed on the subject’s dominant hand. The sensors were positioned across the entirety of the palm and the fingers, except for the fingertips. The pressure at each time step from each sensor was summed and the peak pressure over each trial was extracted. EMG data was collected using a wireless EMG sensors (Delsys Trigno). Data was gathered from the Biceps, Triceps, Middle Deltoid, Posterior Deltoid, Middle Trapezius, Pectoralis Major, and Latissimus Dorsi. The peak values for the wrenching task were then selected for the analysis. All data was normalized to the values of the low height.

RESULTS: The ratio of pressure to the low height grip pressure for the medium height was 1.02 for detach and 0.92 for attach, while the high height pressure ratio was 1.12 for detach and 1.02 for attach. Differences for the highest height level were statistically significant. Of the muscles, only differences in deltoid activation was significant for all cases, and were 1.2 and 4.2 times the low height value for the medium and high height respectively during detach and 2.4 and 5.8 for the attach task.

DISCUSSION: In general, both pressure and EMG activity exhibited some differences with abduction angle. Larger shoulder abduction generally resulted in higher peak muscle activity and an increase in grip pressure. Therefore, this pilot study suggests that the higher meter is placed, the more likely a worker is to experience an arm injury. Further research will substantiate the findings of this study, and investigate the effectiveness of better tool designs to reduce grip pressures and torque to mitigate the effects of shoulder abduction.
Automated Lung Segmentation For Low Resolution CT Scans Of Rats

Benjamin Rizzo\textsuperscript{1}, Steven T. Haworth\textsuperscript{2} and Anne V. Clough\textsuperscript{1,2}

1 Department of Mathematics, Statistics, and Computer Science, Marquette University, Milwaukee, WI, 53233; 2 Zablocki VA Medical Center, Milwaukee, WI

Our laboratory utilizes a dual CT and SPECT imaging system to study lung injury in rats. SPECT imaging involves examining the uptake of radiopharmaceuticals within the lung of control and treated rats. Methods of quantifying relative uptake within the lungs and comparison of right and left lung uptake generally begin with identifying and segmenting the lung region within the 3D reconstructed volume. However, identification of the lung boundaries and the fissure between the left and right lung is not always possible from the SPECT images directly since the radiopharmaceutical may be taken up by other tissues as well. Thus, a low-resolution CT scan is performed, the lung boundaries are identified from the CT image, and the CT region is fused with the SPECT volume to obtain the SPECT lung region. Segmenting rat lungs within the CT volume is particularly challenging due to their unique anatomy, which involves the right lung crossing over into the left side of the thorax. Thus, we have developed an automated segmentation algorithm for low resolution micro-CT scans that utilizes depth maps to detect fissures on the surface of the lung volume. The fissure’s surface location is in turn used to extrapolate the fissure throughout the lung volume. The approach has been validated on phantoms and recently implemented on rat CT images.
Experimental Study of Optimal Energy Weighting in Energy-Resolved CT using a CZT Detector

Franco Rupcich¹ and Taly Gilat Schmidt¹

¹Department of Biomedical Engineering, Marquette University, Milwaukee, WI

**Purpose:** X-ray detectors with energy-resolving capabilities have the potential to improve contrast-to-noise ratio (CNR) compared to conventional detectors. We experimentally investigated the effects of energy bin selection on the improvement in CNR of projection-based and image-based weighted images relative to photon counting during energy-resolved CT. Further, we performed a preliminary investigation of the effects of spectral tailing on the performance of image-based and projection-based weighting.

**Methods and Materials:** We acquired multi-energy CT data of a breast phantom containing a calcium contrast agent using our bench top energy-resolving CT system with a cadmium zinc telluride (CZT) detector. Images were obtained for six different energy-bin combinations using 1) projection-based weighting, for which the energy-bin data is weighted and combined prior to log normalization based on the expected contrast-to-noise-variance ratio in the projection data, and 2) image-based weighting, for which reconstructed energy-bin images are optimally weighted and combined based on the contrast-to-noise-variance ratio in the reconstructed energy-binned images. The CNR for each energy-bin combination for both weighting schemes was compared to that of an image obtained using photon-counting detection.

**Results:** CNR values ranged between 0.85 and 1.01 for the projection-based weighted images and between 0.91 and 1.43 for the image-based weighted images, relative to the CNR for the photon-counting image. The range of CNR values demonstrates the effects of energy-bin selection on CNR for a particular energy-weighting scheme. The non-ideal spectral response of the CZT detector caused spectral tailing, which appears to generally reduce the CNR for the projection-based weighted images. Image-based weighting increased CNR in five of the six bin combinations despite the non-ideal spectral effects.

**Conclusion:** The improvement in CNR for projection-based and image-based weighting relative to photon-counting during energy-resolved CT is dependent on the energy-bin selections. Overall, our results indicate that image-based weighting during energy-resolved CT improves CNR and thus shows potential for reducing breast dose during procedures such as dedicated breast CT. Further studies are required to investigate the performance of each weighting scheme when combined with spectral tailing correction.
Reducing Radiation Dose to the Female Breast During CT Coronary Angiography: A Simulation Study comparing Breast Shielding, Angular Tube Current Modulation, Reduced kV, and Partial Angle Protocols using an Unknown-Location Signal-Detectability Metric

Franco Rupcich¹, Andreu Badal², Lucretiu Popescu², Iacovos Kyprianou², and Taly Gilat Schmidt¹

¹Department of Biomedical Engineering, Marquette University, Milwaukee, WI
²Center for Devices and Radiological Health, US Food and Drug Administration, Silver Spring, MD

Purpose: We compared the performance of five protocols intended to reduce dose to the breast during CT coronary angiography scans using an unknown-location signal-detectability metric.

Methods and Materials: We simulated CT images of an anthropomorphic female thorax phantom for a 120 kV reference protocol and five “dose reduction” protocols intended to reduce dose to the breast: 120 kV partial angle (posteriorly centered), 120 kV tube-current modulated (TCM), 120 kV with shielded breasts, 80 kV, and 80 kV partial angle (posteriorly centered). Two image quality tasks were investigated: the detection and localization of 4 mm, 3.25 mg/mL and 1 mm, 6.0 mg/mL iodine contrast signals randomly located in the heart region. For each protocol, we plotted the signal detectability, as quantified by the area under the exponentially transformed free response characteristic curve (AUC EFROC) estimator ($A_{FE}$), as well as noise and contrast-to-noise ratio (CNR) versus breast and lung dose. In addition, we quantified each protocol’s dose performance as the percent difference in dose relative to the reference protocol achieved while maintaining equivalent $A_{FE}$.

Results: The 80 kV full scan and 80 kV partial angle protocols decreased dose to the breast (80.5% and 85.3%, respectively) and lung (80.5% and 76.7%, respectively) for the 4 mm signal-size task with $A_{FE} = 0.96$, but also resulted in an approximate three-fold increase in image noise. The 120 kV partial protocol reduced dose to the breast (17.6%) at the expense of increased lung dose (25.3%). The TCM algorithm decreased dose to the breast (6.0%) and lung (10.4%). Breast shielding increased breast dose (67.8%) and lung dose (103.4%). The 80 kV and 80 kV partial protocols demonstrated greater dose reductions for the 4 mm task than for the 1 mm task, and the shielded protocol showed a larger increase in dose for the 4 mm task than for the 1 mm task. In general, the CNR curves indicate a similar relative ranking of protocol performance as the corresponding $A_{FE}$ curves, however, the CNR metric overestimated the performance of the shielded protocol for both tasks, leading to corresponding underestimates in the relative dose increases compared to those obtained when using the $A_{FE}$ metric.

Conclusions: The 80 kV and 80 kV partial angle protocols demonstrated the greatest reduction to breast and lung dose, however, the subsequent increase in image noise may be deemed clinically unacceptable. Tube output for these protocols can be adjusted to achieve a more desirable noise level with lesser breast dose savings. Breast shielding increased breast and lung dose when maintaining equivalent $A_{FE}$. The results demonstrated that comparisons of dose performance depend on both the image quality metric and the specific task.
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