5th Annual

Surgery, Intervention, and Engineering Symposium

DECEMBER 14TH | **202 Light Hall**

"Catalyzing Translational Innovation"

presented by

Christopher P. Austin, MD

Director
National Center for Advancing Translational Sciences
National Institutes of Health

Sponsored by

VISE

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Keynote Abstract

"Catalyzing Translational Innovation"

Christopher P. Austin, M.D.

Director, National Center for Advancing Translational Sciences

The process by which observations in the laboratory or the clinic are transformed into demonstrably useful interventions that tangibly improve human health is frequently termed "translation." This multi-stage and multifaceted process is poorly understood scientifically, and the current research ecosystem is operationally not well suited to the distinct needs of translation. As a result, biomedical science is in an era of unprecedented accomplishment without a concomitant improvement in meaningful health outcomes, and this is creating pressures that extend from the scientific to the societal and political.

To meet the opportunities and needs in translational science, NCATS was created as NIH's newest component in December 2011, via a concatenation of extant NIH programs previously resident in other components of NIH. NCATS is scientifically and organizationally different from other NIH Institutes and Centers. It focuses on what is common to diseases and the translational process, and acts a catalyst to bring together the collaborative teams necessary to develop new technologies and paradigms to improve the efficiency and effectiveness of the translational process, from target validation through intervention development to demonstration of public health impact. This talk will provide an overview of NCATS mission, programs, and deliverables, with a view toward future developments.

Christopher P. Austin, M.D.
Symposium Keynote Speaker

Christopher P. Austin, M.D., is director of the National Center for Advancing Translational Sciences (NCATS) at the U.S. National Institutes of Health (NIH). Austin leads the Center's work to improve the translation of observations in the laboratory, clinic and community into interventions that reach and benefit patients—from diagnostics and therapeutics to medical procedures and behavioral changes. Under his direction, NCATS researchers and collaborators are developing new technologies, resources and collaborative research models; demonstrating their usefulness; and disseminating the data, analysis and methodologies for use by the worldwide research community.

Austin's career has spanned the spectrum of translational research, in the public and private sectors. Austin joined NIH in 2002 as the senior advisor to the director for translational research at the National Human Genome Research Institute, where he was responsible for conceptualizing and implementing research programs to derive scientific insights and therapeutic benefit from the newly completed Human Genome Project. While at NHGRI, he founded and directed the NIH Chemical Genomics Center, Therapeutics for Rare and Neglected Diseases program, Toxicology in the 21st Century initiative, and NIH Center for Translational Therapeutics. Upon creation of

NCATS in 2011, he became the inaugural director of the NCATS Division of Pre-Clinical Innovation, and was appointed NCATS director in 2012. Prior to joining NIH, Austin worked at the pharmaceutical company Merck, where he directed programs on genome-based discovery of novel targets and drugs, with a particular focus on schizophrenia and Alzheimer's disease.

Austin is trained as a clinician and geneticist. He trained in internal medicine and neurology at the Massachusetts General Hospital in Boston, and practiced medicine in academic and community hospital settings as well as in urban primary care and in rural Alaska and Africa. He completed a research fellowship in developmental neurogenetics at Harvard, studying genetic and environmental influences on stem cell fate determination. Austin earned an M.D. from Harvard Medical School and A.B. *summa cum laude* in biology from Princeton University.

Participating Laboratories

Advanced Robotics and Mechanism Applications (ARMA)

PI: Nabil Simaan, Associate Professor of Mechanical Engineering & Otolaryngology

ARMA is focused on advanced robotics research including robotics, mechanism design, control, and telemanipulation for medical applications. We focus on enabling technologies that necessitate novel design solutions that require contributions in design modeling and control. ARMA has lead the way in advancing several robotics technologies for medical applications including high dexterity snake-like robots for surgery, steerable electrode arrays for cochlear implant surgery, robotics for single port access surgery and natural orifice surgery. Current and past funded research includes transurethral bladder cancer resection (NIH), trans-oral minimally invasive surgery of the upper airways (NIH), single port access surgery (NIH), technologies for robot surgical situational awareness (National Robotics Initiative), Micro-vascular surgery and micro surgery of the retina (VU Discovery Grant), Robotics for cochlear implant surgery (Cochlear Corporation). We collaborate closely with industry on translation our research. Examples include technologies for snake robots licensed to Intuitive Surgical, technologies for micro-surgery of the retina which lead to the formation of AURIS surgical robotics Inc., the IREP single port surgery robot which has been licensed to Titan Medical Inc. and serves as the research prototype behind the Titan Medial Inc. SPORT (Single Port Orifice Robotic Technology).

Web site: http://arma.vuse.vanderbilt.edu

Lab Youtube Channel: http://www.youtube.com/user/ARMAVU/videos

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Participating Laboratories

Biomedical Elasticity and Acoustic Measurement (BEAM) Laboratory
PI: Brett Byram, Assistant Professor of Biomedical Engineering

The biomedical elasticity and acoustic measurement (BEAM) lab is interested in pursuing ultrasonic solutions to clinical problems. Brett Byram and the BEAM lab's members have experience with most aspects of systems level ultrasound research, but our current efforts focus on advanced pulse sequencing and algorithm development for motion estimation and beamforming. Our motion estimation work focuses on both coarse and fine scale displacements and enables novel devices for tissue stiffness estimation. Related work is focused on non-contrast tissue perfusion measurements with ultrasound. The goal of our beamforming work is to make normal ultrasound images as clear as intraoperative ultrasound, the gold-standard for many applications. We are also developing novel ultrasound transducers to enhance guidance for percutaneous procedures.

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Participating Laboratories

Biomedical Modeling Laboratory (BML)

PI: Michael I. Miga, Harvie Branscomb Professor, Professor of Biomedical Engineering, Radiology & Radiological Sciences, and Neurological Surgery, Vanderbilt University

The focus of the Biomedical Modeling Laboratory (BML) is on new paradigms in detection, diagnosis, characterization, and treatment of disease through the integration of computational models into research and clinical practice. With the continued improvements in high performance computing, the ability to translate computational modeling from predictive roles to ones that are more integrated within diagnostic and therapeutic applications is becoming a rapid reality. With respect to therapeutic applications, efforts in deformation correction for image-guided surgery applications in brain, liver, kidney, and breast are being investigated. Other applications in deep brain stimulation, ablative therapies, neoadjuvant chemotherapy, and convective chemotherapy are also being investigated. With respect to diagnostic imaging, applications in elastography, strain imaging, model-based chemotherapeutic tumor response and radio-therapy response parameterizations are also of particular interest. The common thread that ties the work together is that, throughout each research project, the integration of mathematical models, tissue mechanics, instrumentation, and analysis is present with a central focus at translating the information to directing therapy/intervention or characterizing tissue changes for diagnostic value.

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Participating Laboratories

Vanderbilt Biophotonics Center

PI: Anita Mahadevan-Jansen, Orrin H. Ingram Professor of Biomedical Engineering, Professor of Neurological Surgery, Vanderbilt University

The Vanderbilt Biophotonics Center is an interdisciplinary research center at the intersection of the College of Arts and Science, the School of Engineering and the School of Medicine that brings together faculty, post-doctoral fellows, graduate and undergraduate students dedicated to biophotonics research. VBC provides a state-of-the-art research facility and a collaborative environment and includes shared core facilities and resources for research that spans everything from fundamental discovery to clinical translation. Research is organized into 3 thrust areas: Cancer Photonics Neurophotonics and Multi-scale biophotonics. Other research interests include application of optical techniques in a variety of other areas such as diabetes research, neonatology, ophthalmology, critical care, surgery, obstetrics, and orthopedics for clinical translation as well as fundamental research. Further, since many of our team are engineers and physicists, research is also focused on the discovery of new optical methodologies and the support needed to advance current technologies to new levels. Example projects include near-infrared fluorescence for the detection of the parathyroid gland in endocrine surgery, optical metabolic imaging to assess therapeutic response in breast cancers and development of infrared neural stimulation to modulate the electrical response of the nervous system without the need for genetic or other external mediators.

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Participating Laboratories

Computational Flow Physics and Engineering (CFPE) Laboratory

PI: Haoxiang Luo, Associate Professor of Mechanical Engineering

High-fidelity modeling and simulations of fluid flows provide critical understand of many complex systems and have become an increasingly important tool in engineering for design and innovations. In biomedical areas, computational fluid dynamics and computational fluid-tissue interaction will lead to novel tools for improved diagnosis, therapy, and surgery planning. In our lab, we develop and utilize computational methods to study biological and biomedical flows (either gas or liquid), especially those involving fluid-structure interactions. The current thrusts focus on aerodynamics of animal swimming, vocal fold modeling in human phonation, and hemodynamics of heart valves and blood vessels.

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Participating Laboratories

CAOS - Computer Assisted Otologic Surgery lab

PI: Robert F Labadie, Professor of Otolaryngology- Head and Neck Surgery, Professor of Biomedical Engineering

The Computer-Assisted Otologic Surgery lab consists of members with clinical and engineering background from Otolaryngology, Electrical Engineering and Computer Science, and Mechanical Engineering. The aim of the lab is to develop methods and tools to enable and assist in minimally-invasive surgeries. Some of the projects the group is current working on include minimally-invasive image-guided targeting of ear structures specifically the cochlea, the endolymphatic sac, and the petrous apex, endoscopic visualization of the cochlea, assessment of electrode placement and audiological outcomes in cochlear implant patients, utilization of robots to perform mastoidectomy, and development of bone-attached parallel robots for skull-based surgery. Equipment available in the lab includes Polaris Spectra (Northern Digital, Waterloo, Ontario, Canada), MicronTracker (Claron Technology Inc, Toronto, Ontario, Canada), a XarTrax steerable laser system (Traxtal, Inc, Toronto, Canada), two robots--a Mitsubishi RV-3S (Mitsubishi Electric & Electronics USA, Inc., Cypress, CA) and a Motoman YR-SV035 (Motoman, Inc., West Carrollton, OH), two surgical stations with electric and pneumatic drills, a rigid endoscope with 1.7 mm diameter explorENT 23-5200 (Gyrus Acmi, Southborough, MA) and a 3 Megapixel USB camera EM310C (BigCatch, Torrance, CA) as well as a video processer unit for micro cameras IntroSpicio 120 (Medigus Ltd., Omer, Israel) and a DVI2USB converter (Epiphan Systems Inc., Ottawa, Ontario, Canada) for digital recordings of video data, surgical microscopes, two CNC milling machines, FARO Gage-Plus measuring system (FARO Technologies, INC., Atlanta, GA), and a xCAT portable fpVCT scanner (Xoran Technologies; Ann Arbor, MI).

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Participating Laboratories

Grissom Laboratory: MRI-Guided Focused Ultrasound

PI: William Grissom, Assistant Professor Biomedical Engineering, Vanderbilt University

A major research focus of the Grissom laboratory is MRI guidance of high intensity focused ultrasound surgery. MRI-guided high intensity focused ultrasound surgery (FUS) is a promising technique for the next generation of non-invasive therapy systems. One important feature of FUS lies in its ability to apply ultrasound from outside the body, without any skin puncture or incision. The ultrasound energy can be focused to a point within the body, with minimal heating of the intervening tissues. MR imaging is used both for treatment planning and to provide temperature measurements during the procedure. The temperature maps are used both to dynamically control the FUS beam during the procedure, and to assess thermal dose afterwards. Our group is focused on the development of MR imaging methods for FUS surgery guidance, including real-time temperature imaging sequences, algorithms to reconstruct temperature maps, and MRI-based methods to autofocus ultrasound beams through bone and inhomogeneous tissue. We also are interested in the development of imagining techniques to exploit novel temperature contrast mechanisms, and algorithms to dynamically and automatically steer and control the power of the FUS beam. Our current clinical applications are ablation of uterine fibroids and diffuse adenomyosis, anti-tumor immune response modulation of breast cancer, modulation of drug uptake in pancreatic cancer, and tumor and tissue ablation in the brain for functional neurosurgery, blood-brain barrier disruption, and sonothrombolysis for treatment acute ischemic stroke. For further information about the lab, visit wgrissom.com.

Contact: will.grissom@vanderbilt.edu

Participating Laboratories

Joos Laboratory- Ophthalmology Research

PI: Karen Joos, M.D., Ph.D., Joseph and Barbara Ellis Professor of Ophthalmology and Visual Sciences, Vanderbilt University Medical Center, and Biomedical Engineering, Vanderbilt University

The surgical research program is designed to investigate the development of innovative surgical methods and the improvement of existing techniques to improve the outcomes of ophthalmic surgery. Approaches include the development and integration of a novel intraocular B-scan OCT probe with surgical instruments to improve visualization of structures during ophthalmic surgery, and the integration of the imaging probes with robot-assisted control for precise tissue manipulation. The Joos and Simaan laboratories have a continuing long-standing collaboration. A new collaboration has developed between the Joos and Tao laboratories.

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Participating Laboratories

Laboratory for the Design and Control of Energetic Systems

PI: Eric Barth, Associate Professor of Mechanical Engineering, Vanderbilt University

The Laboratory for the Design and Control of Energetic Systems seeks to develop and experimentally apply a systems dynamics and control perspective to problems involving the control and transduction of energy. This scope includes multi-physics modeling, control methodologies formulation, and model-based or model-guided design. The space of applications where this framework has been applied includes nonlinear controllers and nonlinear observers for pneumatically actuated systems, a combined thermodynamic/system dynamics approach to the design of free piston green engines of both internal combustion and external heat source varieties, modeling and model-based design and control of monopropellant systems, and energy-based approaches for single and multiple vehicle control and guidance. Most recent research efforts have focused on high efficiency hydraulic accumulators for regenerative braking in hybrid vehicles, a vibration energy harvester for bridge monitoring, and MRI compatible pneumatically actuated robots.

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Participating Laboratories

Laryngeal Biology Laboratory

PI: Bernard Rousseau, Associate Vice Chair for Research, Otolaryngology; Chancellor Faculty Fellow and Associate Professor, Otolaryngology, Hearing and Speech Sciences, and Mechanical Engineering, Vanderbilt University

There are several significant stresses (e.g. impact, stretching, and shear) that develop within the vocal fold tissues during vibration that differ in magnitude, direction, and distribution. It has been suggested that the high impact stress at the mid-portion of the vocal folds results in increased trauma to this region during phonation. This area has been described as a critical strike zone, or region of maximum impact, where the greatest collision between the two medial surfaces occurs during phonation. The Laryngeal Biology Laboratory under the direction of Bernard Rousseau, Ph.D., and the Computational Flow Physics Laboratory under the direction of Haoxiang Lou, Ph.D., are working towards the development of patient specific high-fidelity computational models to quantify the magnitude and spatial distribution of mechanical stresses during phonation. We are also working on the development of pre-operative surgical planning tools to improve outcomes in the treatment of vocal fold paralysis. This work is performed in collaboration with C. Gaelyn Garrett, M.D., Professor, Vice-Chair, and Medical Director of the Vanderbilt Voice Center and David Francis, M.D., Assistant Professor of Otolaryngology, Vanderbilt Voice Center.

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Participating Laboratories

Mawn Laboratory

PI: Louise Mawn, MD, Associate Professor Ophthalmology, Vanderbilt University

The laboratory of Dr. Louise Mawn of the Vanderbilt Eye Institute exists in collaboration with Dr. Robert Galloway of Biomedical Engineering, Dr. Bennett Landman of Electrical Engineering, and Dr. Seth Smith of the Imaging Institute, focuses on improving understanding, treatment and imaging of orbital disease. Specific goals include improving orbital surgery using minimally invasive techniques and image guidance. The surgical and medical treatment of disease of the orbit is challenging in part because of the difficulty reaching the space behind the eye. The orbit houses the optic nerve; disease of the optic nerve is the leading cause of irreversible blindness worldwide. The laboratory uses anatomical studies, imaging technology and biomedical engineering to improve approaches to the optic nerve and retrobulbar space.

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Participating Laboratories

Medical-image Analysis and Statistical Interpretation (MASI) Laboratory

PI: Bennett Landman, Electrical Engineering, Biomedical Engineering, Computer Science, Radiology and Image Science, Vanderbilt University

Three-dimensional medical images are changing the way we understand our minds, describe our bodies, and care for ourselves. In the MASI lab, we believe that only a small fraction of this potential has been tapped. We are applying medical image processing to capture the richness of human variation at the population level to learn about complex factors impacting individuals. Our focus is on innovations in robust content analysis, modern statistical methods, and imaging informatics. We partner broadly with clinical and basic science researchers to recognize and resolve technical, practical, and theoretical challenges to translating medical image computing techniques for the benefit of patient care.

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Participating Laboratories

Medical Engineering and Discovery (MED) Laboratory

PI: Robert J. Webster III, Mechanical Engineering, Electrical Engineering, Otolaryngology, Neurological Surgery, and Urologic Surgery

The Vanderbilt School of Engineering's Medical Engineering and Discovery (MED) Laboratory pursues research at the interface of surgery and engineering. Our mission is to enhance the lives of patients by engineering better devices and tools to assist physicians. Much of our current research involves designing and constructing the next generation of surgical robotic systems that are less invasive, more intelligent, and more accurate. These devices typically work collaboratively with surgeons, assisting them with image guidance and dexterity in small spaces. Creating these devices involves research in design, modeling, control, and human interfaces for novel robots. Specific current projects include needle-sized tentacle-like robots, advanced manual laparoscopic instruments with wrists and elbows, image guidance for high-accuracy inner ear surgery and abdominal soft tissue procedures, and swallowable pill-sized robots for interventions in the gastrointestinal tract.

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Participating Laboratories

Medical Image Processing (MIP) Laboratory

PI: Benoit Dawant, Professor Electrical Engineering and Computer Science, Biomedical Engineering, Radiology and Radiological Sciences

The medical image processing (MIP) laboratory of the Electrical Engineering and Computer Science (EECS) Department conducts research in the area of medical image processing and analysis. The core algorithmic expertise of the laboratory is image segmentation and registration. The laboratory is involved in a number of collaborative projects both with others in the engineering school and with investigators in the medical school. Ongoing research projects include developing and testing image processing algorithms to (1) automatically localize radiosensitive structures to facilitate radiotherapy planning, (2) assist in the placement and programming of Deep Brain Stimulators used to treat Parkinson's disease, (3) localize automatically structures that need to be avoided while placing cochlear implants, (4) develop methods for cochlear implant programming or (5) track brain shift during surgery. The laboratory expertise spans the entire spectrum between algorithmic development and clinical deployment. Several projects that have been initiated in the laboratory have been translated to clinical use or have reached the stage of clinical prototype at Vanderbilt and at other collaborative institutions. Components of these systems have been commercialized.

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Participating Laboratories

Merryman Mechanobiology Laboratory (MML)

PI: W. David Merryman, Associate Professor, Biomedical Engineering, Pharmacology, Medicine and Pediatrics, Vanderbilt University

The Merryman Mechanobiology Laboratory +(MML) is devoted to cardiovascular and pulmonary mechanobiology research with emphasis on cellular response and functional changes (phenotypic and biosynthetic) to altered mechanical stimuli and various biochemical agents. Areas of expertise include: cellular and soft tissue biomechanics, in-vitro bioreactor environments for tissue engineering, and mechanistic studies of cytokine activity and mechanical stimuli. Primary laboratory goals are to elucidate the mechanisms leading to multiple cardiovascular diseases and develop non-surgical strategies to prevent and treat them, with particular focus on heart valves.

The Merryman MechanoBiology Laboratory has four areas of research focus: Mechanobiology – the study of how mechanical forces or deformations alter cellular signaling, phenotype, and biosynthetic function; GPCR targeted drug strategies, mechanobiology and we have begun exploring potential therapeutic strategies to prevent heart valve disease via serotonergic receptors; General area of percutaneous interventions for heart valve disease where we are currently developing a novel catheter for percutaneous treatment of myxomatous mitral valve disease by altering the intrinsic biomechanical compliance of the mitral valve leaflets; and Mechanically tunable biomaterial for cardiovascular tissue engineering. WE are developing unable biomaterials that can be dynamically modified via multiple mechanisms to facilitate endothelial-to-mesenchymal transformation.

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Participating Laboratories

Morgan Lab

PI: Vicky Morgan, Associate Professor, Radiology & Biomedical Engineering, Institute of Imagine Science (VUIIS), Vanderbilt University

The Morgan Laboratory works closely with the departments of Neurology and Neurosurgery developing functional Magnetic Resonance Imaging (fMRI) methods to improve neurosurgical outcomes. One main focus is to use fMRI to localize eloquent cortex in the brain in order to minimize functional and cognitive deficits post resection. Another large area of research is in mapping seizure networks in temporal lobe epilepsy using both functional and diffusion weighted MRI. By localizing and quantifying the evolution of these networks overs years of duration of seizures, we aim to elucidate the functional and structural effects of seizures and predict post-surgical seizure and cognitive outcome. Ultimately, we aim to use MRI to fully characterize the spatial and temporal impacts of seizures across the brain to optimize their treatment.

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Fissell Laboratory

PI: William H. Fissell, Associate Professor of Medicine, Vanderbilt University

Our laboratory applies physical and mathematical tools to address unmet needs in care of patients with kidney disease and kidney failure. Our team developed the first new membrane technology for blood separations in 30 years. This high-efficiency membrane allows us to construct miniaturized, implantable devices for renal care.

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Participating Laboratories

Orthopaedic Biomechanics Lab

PI: Jeffry Nyman, Assistant Professor, Surgery – Orthopaedics, Vanderbilt University

The ultimate goal of the research in our lab is to lower the number of bone fractures associated with osteoporosis, diabetes, cancer, genetic diseases, and aging. Towards that end, we investigate ways to improve the clinical assessment of fracture risk and to identify regulators of bone toughness (lack of brittleness). Specifically, there are projects in the lab i) to determine whether matrix-bound water and pore water, as determined by 1H Nuclear Magnetic Resonance (or MRI), can explain age- and diabetes-related decreases in bone's resistance to fracture, ii) to identify the determinants of matrix-bound water, and iii) to elucidate the mechanisms by which tissue confers resistance to crack growth. In addition, we are developing Raman Spectroscopy techniques to assess tissue organization and composition as a potential biomarker of bone fragility. This technology could potentially be transferred to a hand-held probe for intra-operative use during orthopaedic surgeries, thereby providing real-time information on the quality of bone tissue.

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OR Analytics Laboratory

PI: Alexander Langerman, Assistant Professor, Otolaryngology Department, Vanderbilt University

The OR Analytics Lab focuses on novel methods of real-time surgical data collection and analysis.

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Participating Laboratories

Science and Technology for Robotics in Medicine (STORM) Lab

Director STORM Lab USA and PI: Keith L. Obstein, Division of Gastroenterology, Hepatology, and Nutrition; Department of Mechanical Engineering—Vanderbilt University

Director STORM Lab UK and PI: Pietro Valdastri, School of Electronic and Electrical Engineering—University of Leeds; Department of Mechanical and Electrical Engineering, Divisions of Gastroenterology, Hepatology and Nutrition—Vanderbilt University

At the STORM Lab we strive to improve the quality of life for people undergoing endoscopy and abdominal surgery by creating miniature and non-invasive capsule robots.

The continuous quest for miniaturization has made the science fiction vision of miniature capsule robot working inside the human body come true. At the STORM Lab, we are designing and creating mechatronic and self-contained devices to be used inside specific districts of the human body to detect and cure diseases in a non-invasive and minimally invasive manner.

Capsule robots represent a challenging paradigm for both research and learning. They embed sensors, actuators, digital intelligence, miniature mechanisms, communication systems, and power supply, all in a very small volume. Capsule robots may be autonomous or teleoperated, they can work alone or as a team, and they can be customized to fulfill specific functions. We are currently applying capsule robot technologies to early detection and treatment of gastrointestinal cancers (i.e. colorectal cancer, gastric cancer) and are developing a new generation of surgical robots that can enter the patient's abdomen by a single tiny incision. Building upon these competences, we are always ready to face new challenges by modifying our capsule robots to emerging medical needs.

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Participating Laboratories

Diagnostic Imaging and Biophotonics Laboratory

PI: Yuankai (Kenny) Tao, Assistant Professor of Biomedical Engineering, Vanderbilt University

The Diagnostic Imaging and Biophotonics Laboratory develops novel optical imaging systems for clinical diagnostics and therapeutic monitoring in ophthalmology and oncology. Biomedical optics enable non-invasive subcellular visualization of tissue morphology, biological dynamics, and disease pathogenesis. Our ongoing research primarily focuses on clinical translation of therapeutic tools for image-guided intraoperative feedback using modalities including optical coherence tomography (OCT), which provides high-resolution volumetric imaging of weakly scattering tissue; and nonlinear microscopy, which has improved molecular-specificity, imaging depth, and contrast over conventional white-light and fluorescence microscopy. Additionally, we have developed optical imaging techniques that exploit intrinsic functional contrast for *in vivo* monitoring of blood flow and oxygenation as surrogate biomarkers of cellular metabolism and early indicators of disease. The majority of our research projects are multidisciplinary collaborations between investigators in engineering, basic sciences, and medicine.

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Submitted Abstracts

1. A Cochlear Implant Phantom for Evaluating CT Acquisition Parameters

Srijata Chakravorti (Department of Electrical Engineering and Computer Science), Brian J. Bussey (Department of Radiology), Yiyuan Zhao (Department of Electrical Engineering and Computer Science), Benoit M. Dawant (Department of Electrical Engineering and Computer Science), Robert F. Labadie (Department of Otolaryngology - Head & Neck Surgery), and Jack H. Noble (Department of Electrical Engineering and Computer Science)

Cochlear Implants (CIs) are surgically implantable neural prosthetic devices used to treat profound hearing loss. Recent literature indicates that there is a correlation between the positioning of the electrode array within the cochlea and the ultimate hearing outcome of the patient, indicating that further studies aimed at better understanding the relationship between electrode position and outcomes could have significant implications for future surgical techniques, array design, and processor programming methods. Post-implantation high resolution CT imaging is the best modality for localizing electrodes and provides the resolution necessary to visually identify electrode position, albeit with an unknown degree of accuracy depending on image acquisition parameters, like the HU range of reconstruction, radiation dose, and resolution of the image. In this work, we report on the development of a phantom that will both permit studying which CT acquisition parameters are best for accurately identifying electrode position and serve as a ground truth for evaluating how different electrode localization methods perform when using different CT scanners and acquisition parameters. We conclude based on our tests that image resolution and HU range of reconstruction strongly affect how accurately the true position of the electrode array can be found by both experts and automatic analysis techniques. The results presented in this work demonstrate that our phantom is a versatile tool for assessing how CT acquisition parameters affect the localization of CIs.

Submitted Abstracts

2. A novel human-to-phantom dataset for the rapid validation of IGLS registration techniques

Jarrod A. Collins [1], Jared A. Weis [1], Amber L. Simpson [2], William R. Jarnagin [2], and Michael I. Miga [1,3,4]

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[2] Memorial Sloan-Kettering Cancer Center, Department of Surgery, New York, NY USA
[3] Vanderbilt University Medical Center, Department of Radiology and Radiological Sciences, Nashville, TN USA
[4] Vanderbilt University Medical Center, Department of Neurological Surgery, Nashville, TN USA

In open image-guided liver surgery (IGLS), a sparse digitization of the intraoperative organ surface can be acquired to drive image-to-physical registration. Clinical validation of such registration methods is challenged due to the difficulty in obtaining data representative of the true state of intraoperative organ deformation. The encumbrance of intraoperative volumetric validation (either by partial volume methods such as tracked ultrasound or full volumetric imaging) is considerable and adds impetus for a new way to characterize methods quickly. We present a novel human-to-phantom validation framework that transposes surface collection patterns from in vivo IGLS procedures onto a fully-characterized hepatic deformation phantom for the purpose of validating surface-driven, volumetric IGLS registration methods. An important feature of this approach is that it centers on combining workflow-realistic data acquisition and surgical deformations that are appropriate in magnitude and behavior. Using this approach, we investigate volumetric target registration error (TRE) with the only current commercial rigid IGLS and our improved nonrigid registration methods. As a proof of concept using the human-to-phantom data, TRE following routine rigid registration was 10.9 ± 0.6 mm while TRE following our improved nonrigid registration method was 6.7 ± 0.9 mm (i.e. an improvement of ~39%). The work reported herein realizes a novel tractable approach for the rapid validation of image-to-physical registration methods and demonstrates promising results for our correction methods. While we report on our particular approaches, the described framework has broader impact by demonstrating how clinical workflow data can be combined with a realistic phantom for rapid methodological testing.

Submitted Abstracts

3. A Novel Platform Technology for Cytosolic Peptide Delivery with Endosomolytic Nano-Polyplexes Applied to Vascular Graft Intimal Hyperplasia

Evans BC [1], Hocking KM [1], Osgood MJ [2], Voskresensky I [2], Dmowska J [1], Kilchrist KV [1], Brophy CM [2,3], Duvall CL [1]

[1] Vanderbilt University Department of Biomedical Engineering, Nashville, TN, USA.
[2] Vanderbilt University Medical Center Department of Surgery, Division of Vascular Surgery, Nashville, TN, USA.
[3] Veterans Affairs Medical Center, VA Tennessee Valley Healthcare System, Nashville, TN, USA.

Autologous vein grafts are commonly used for coronary and peripheral artery bypass but have a high incidence of intimal hyperplasia (IH) and failure. Here, a nano-polyplex (NP) approach is presented that efficiently delivers a MAPKAP kinase 2 inhibitory peptide (MK2i) to graft tissue in order to improve long-term patency by inhibiting pathways that initiate IH. In vitro testing in human vascular smooth muscle cells revealed that formulation into MK2i-NPs increased cell internalization, endosomal escape, and intracellular half-life of MK2i. This efficient delivery mechanism enabled MK2i-NPs to sustain potent inhibition of inflammatory cytokine production and migration in vascular cells. At the molecular level, MK2i-NPs blocked inflammatory and migratory signaling in human saphenous vein, as confirmed by reduced phosphorylation of the post-transcriptional gene regulator heterogeneous nuclear ribonucleoprotein A0 (hnRNP A0), the transcription factor cAMP element binding protein (CREB), and the chaperone heat shock protein 27 (HSP-27). Functionally, MK2i-NPs inhibited IH in human saphenous vein ex vivo. In a rabbit vein transplant model, a 30 minute intraoperative graft treatment with MK2i-NPs significantly reduced in vivo IH 28 days post-transplant ($p<0.01$ relative to untreated or free MK2i treated grafts). The decrease in IH corresponded to decreased cellular proliferation and a contractile vascular smooth muscle cell phenotype. These combined results confirm that MK2i-NPs potently reduce vein graft failure and highlight a new approach to the delivery of peptide-based therapeutics to cells and tissue.

Submitted Abstracts

4. An Experimental Comparison of Two User Interface Designs for a Hand-Held Surgical Robot

Margaret F. Rox, Richard J. Hendrick, S. Duke Herrell, and Robert J. Webster III   Vanderbilt Department of Mechanical Engineering Vanderbilt Institute in Surgery and Engineering (VISE)

As surgeries become less invasive, there is an increasing interest in hand-held medical robots because of their ability to maintain clinical workflow. User interfaces are an important component of hand-held surgical robots because they help the surgeon learn how to use these robots quickly and effectively. This poster outlines an experiment comparing two user interfaces for an existing hand-held robotic device. The device provides the surgeon with two dexterous manipulators (concentric tube robots) delivered through the port of a transurethral endoscope. The original user interface for the robot featured a pivoting thumb joystick and a unidirectional finger trigger which commanded the end effectors. This user interface was used in a previous study where surgeons found they could learn the interface mappings, but had some difficulty with the unidirectional trigger. The new user interface employs a sliding joystick and a bidirectional dial to replace the trigger. To determine whether the new user interface would be an improvement, an experiment was designed where a user performed 3D path following with both interfaces. The time to complete the path, mean error, maximum error, and percentage of time manipulator was in large error (greater than 2 mm) were recorded using a magnetic tracking system. The results demonstrated that the new user interface improved the user's ability to follow a 3D path, but future work is needed to fully validate the study.

Submitted Abstracts

5. An MRI-Compatible Robot for Intracerebral Hemorrhage Removal

Yue Chen [1,2], Isuru S. Godage [1,2], Saikat Sengupta [3], Cindy Lin Liu [1,2], Kyle D. Weaver [4], Eric J. Barth [1,2], Robert J. Webster, III [1,2,4]

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Intracerebral Hemorrhage (ICH) is the deadliest form of stroke and occurs when blood, leaked from a ruptured vessel pools in the brain forming a pool of semi-coagulated blood called a hematoma. The 30-day mortality rate is 43% with half of the deaths occurring in the acute phase, which motivates the need for safe and rapid treatment. However, literature reviews show no significant benefit of surgical removal vs. 'watchful waiting', despite the potential value of decompressing the brain. Recent studies have shown that a robotic needle made from curved, concentric, elastic tubes can reach a hemorrhagic site to successfully aspirate the hematoma. The need for intraoperative imaging was motivated by the fact that the brain shifts during aspiration, collapsing to fill the cavity left by voided blood. This approach has the potential advantage of 'one stop shopping', since it is appealing to treat ICH immediately after diagnosis while the patient is still in the CT scanner. However, CT also has the drawback of requiring ionizing radiation, as well as providing only intermittent images rather than real-time information. In this poster, we presents the preliminary study of a novel MR-compatible steerable needle robot for ICH removal. The needle tip positioning tests showed that the robot's kinematic model is accurate, although future tests in the MRI scanner using MRI image feedback will be needed to evaluate overall system accuracy with images in the loop. Fully exploring these will be facilitated by the purpose-built MRI-compatible robot described for the first time in this paper.

Submitted Abstracts

6. Aperture Domain Model Image Reconstruction (ADMIRE) with Plane Wave Synthesis

Kazuyuki Dei, Jaime Tierney, Brett Byram BEAM Lab, Department of Biomedical Engineering, Vanderbilt University

Motivation/Objective: Today's high-end ultrasound systems can provide high quality images, but reverberation and off-axis scattering often degrade the realized image quality. To suppress these effects, we introduced a model-based clutter suppression algorithm, called aperture domain model image reconstruction (ADMIRE). Previously, we demonstrated ADMIRE substantially improves image quality of in vivo data obtained from focused transmit beams sequences. Given the recent interest in high-speed imaging with full insonification sequences, we were interested in ADMIRE's ability to suppress clutter from unfocused transmit sequences. Additionally, unfocused beam sequences are often used in conjunction with synthetic aperture processing. The objective is to evaluate the performance of ADMIRE in conjunction with plane wave transmit sequencing and synthetic aperture processing.   Contribution/Methods: We employed simulated phantoms using Field II and tissue-mimicking phantoms to evaluate ADMIRE applied to plane wave sequencing. We generated images acquired from plane waves with and without synthetic aperture and measured contrast and contrast-to-noise ratio (CNR). We also assessed ADMIRE using resolution phantoms with a point target at 3 cm depth. Finally, we applied this to an in vivo carotid artery. Results: For simulated cyst images formed from a single plane wave, the contrast for DAS and ADMIRE are 15.64 dB and 28.34 dB, respectively, while the CNR are 1.76 dB and 3.90 dB, respectively. Based on these findings, ADMIRE improves plane wave image quality. We observed qualitative improvements from the in vivo imaging case.

Submitted Abstracts

7. Automatic selection of landmarks in T1-weighted head MRI with regression forests for image registration initialization

Jianing Wang, Yuan Liu, Ph.D., Jack H. Noble, Ph.D., and Benoit M. Dawant, Ph.D. Dept. of Electrical Engineering and Computer Science, Vanderbilt University, Nashville, TN 35235, USA

Image registration is at the core of many applications in medical imaging but registration methods often depend on a good initialization to lead to accurate results. Prior work has shown that landmark-based point set registration is a good approach to initialize the registration process but the selection of landmarks is important. Landmarks should cover the entire structure and make the correspondences between individuals as robust as possible. In this work, we present a learning-based method to automatically find a set of robust landmarks in 3D MR image volumes of the head to initialize non-rigid transformations. Our dataset contains images of 101 individuals, the images are partitioned into a training dataset of 60 images that is used to train regression forests to localize a set of landmarks, a second training set of 20 images that is used to identify among the set of landmarks which ones are the most robust, a testing set of 20 images, and one atlas image. Our technique includes 4 training steps: (1) the generation of the candidate landmark set using the atlas image, (2) the creation of a series of RF models that are each trained to localize one landmark, (3) the localization of the candidate landmarks in the second training set and (4) the selection of the most reliable landmarks using a random sample consensus (RANSAC) algorithm and the second training set. In the testing phase, the most reliable landmarks are localized in unknown volumes and they are used to compute a thin-plate splines transformation that registers the atlas to the volume. We show that our method leads to good registration initialization results.

Submitted Abstracts

8. Breast tissue stiffness estimation for surgical guidance using gravity-induced excitation

Rebekah H. Griesenauer [1,2], Jared A. Weis [1,2], Lori R. Arlinghaus [3], Michael I. Miga [1,2,4,5],

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Tissue stiffness interrogation is fundamental in breast cancer diagnosis and treatment. Furthermore, biomechanical models for predicting breast deformations have been created for several breast cancer applications. Within these applications, constitutive mechanical properties must be defined and the accuracy of this estimation directly impacts the overall performance of the model. In this study, we present an image-derived computational framework to obtain quantitative, patient specific stiffness properties for application in breast cancer surgery and interventions. The method uses two MR acquisitions of the breast in different supine gravity-loaded configurations to fit mechanical properties to a biomechanical breast model. A reproducability assessment of the method was performed in a test/retest study using healthy volunteers and was further characterized in simulation. In five human subjects, the within subject coefficient of variation ranged from 10.7\% to 27\% and the intraclass correlation coefficient ranged from 0.91-0.994 for assessment of fibroglandular and adipose tissue stiffness. In simulation, fibroglandular content and deformation magnitude were shown to have significant effects on the shape and convexity of the objective function defined by image similarity. These observations provide an important step forward in characterizing the use of nonrigid image registration methodologies in conjunction with biomechanical models to estimate tissue stiffness. In addition, the results suggest that stiffness estimation methods using gravity-induced excitation can reliably and feasibly be implemented in breast cancer surgery/intervention workflows.

Submitted Abstracts

9. Characterization of Calyceal Anatomy Using CT Image Segmentation

Smita De, M.D., Ph.D., Vanderbilt University Medical Center Department of Urologic Surgery, Vanderbilt Institute in Surgery and Engineering; Yuankai Huo, Ph. C., Department of Electrical Engineering and Computer Science; Bennett Landman, Ph.D., Department of Electrical Engineering; Stanley Duke Herrell, M.D., F.A.C.S., Vanderbilt University Medical Center Department of Urologic Surgery, Vanderbilt Institute in Surgery and Engineering

Nephrolithiasis is a highly prevalent disease that leads to significant medical costs and patient morbidity. There has been minimal characterization of the renal collecting system where kidney stones form and are treated. The availability of a large number of high resolution digital CT scans along with powerful software capable of automated image segmentation and computational modeling provides a novel opportunity to improve our understanding of calyceal anatomy. In this pilot study, we evaluate the feasibility of using our segmentation algorithms to identify and appropriately render three-dimensional reconstructions of the calyceal system, which can then be used for further anatomic analysis. The Vanderbilt Research Derivative was used to identify patients with normal upper urinary tract systems on CT urograms. The delayed images from two representative CT urograms were converted to NIFTI files and resampled to 0.5 mm isotropic resolution. Cubic regions containing left and right kidneys were manually cropped after which the images were segmented using a band pass filter. Rendered three-dimensional reconstructions were consistent with anatomy observed on the original CT scans and were used to calculate collecting system volumes. Next steps will include automation of this process and more complex evaluation of anatomic dimensions. Our methodology provides a foundation upon which we can build a variety of algorithms to perform population-based analyses of various collecting system parameters (i.e. length, diameter, curvature), which could then be used to improve medical management of nephrolithiasis and design of instruments for surgical stone treatment.

Submitted Abstracts

10. Clinically translatable tools for assessment of sugar-induced changes in human bone tissue quality

Sasidhar Uppuganti [1], Mathilde Granke [1], Amy Creecy [1], Calen Leverant [1], Shoshana Hodes [2], Jeffry S. Nyman [1,3]

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Advanced glycation end-products (AGEs) accumulate with age and disease in bone and embrittle the organic matrix, thereby decreasing fracture resistance [1]. Current clinical assessment of bone mineral density does not accurately predict fracture risk. There is a need to advance matrix-sensitive tools to quantitatively assess AGE accumulation. Raman Spectroscopy (RS) and Reference Point Indentation (cRPI) are two such clinically viable tools. We hypothesized that inducing AGEs alters the Amide I band in the RS spectra and reduces the bone tissue resistance to cyclic microindentation. Four cortical bone segments were extracted from the medial quadrant of femur mid-shaft of ten cadavers (5/gender; 55±5 yrs). Paired bones were then randomly assigned to incubate in two sugars (Ribose and D-glucose) at varying concentrations (0 mM and 500 mM; each supplemented with 0.02% sodium azide to prevent protein degradation) for 4 weeks (R0 & R5) or 8 weeks (G0 & G5) under monitored conditions (temperature=37 ± 0.5 °C and pH range=7.0 to 7.5). RS was collected from each sample at 2 sites and then cRPI was performed on the contralateral surface; a piece of each sample was also hydrolyzed to quantify pentosidine (PEN), an AGE marker, using an HPLC assay. Sugar-induced changes caused significant crosslinking in both ribose ($p=0.002$) and D-glucose ($p=0.010$) samples, as seen by HPLC. Ribation, but not D-glucose, perturbed the secondary structure of collagen ($p<0.0001$). Interestingly, the sub-band ratio 1667:1605, not the so-called collagen crosslink ratio (1667:1690), was the most sensitive to sugar incubation (R0-R5 $p=0.001$). Among cRPI properties, indentation distance (TID) was reduced for the ribose-induced crosslinked tissues while others were insensitive. As such, RS potentially could be developed to improve fracture risk assessment through clinical measurements of the secondary structure of collagen (Amide I).

Submitted Abstracts

11. Coffee: The Key to Safer Image-Guided Surgery

Patrick Wellborn, Mechanical Engineering Neal Dillon, Mechanical Engineering Paul Russell, MD, Department of Otolaryngology Robert Webster III, PhD, Mechanical Engineering

Purpose: Accurate image guidance requires a rigid connection between tracked fiducial markers and the patient, which cannot be guaranteed by current non-invasive attachment techniques. We propose a new granular jamming approach to firmly, yet non-invasively, connect fiducials to the patient.   Methods: Our granular jamming cap surrounds the head and conforms to the contours of the patient's skull. When a vacuum is drawn, the device solidifies in a manner conceptually like a vacuum-packed bag of ground coffee, providing a rigid structure that can firmly hold fiducial markers to the patient's skull. By using the new Polaris Krios optical tracker we can also use more fiducials in advantageous configurations to reduce registration error.   Results: We compared our new approach against the a clinically used headband-based fiducial fixation device, under perturbations that could reasonably be expected to occur in a real-world operating room. In bump testing we found that the granular jamming cap reduced average TRE at the skull base from 2.29 mm to 0.56 mm and maximum TRE at the same point from 7.65 mm to 1.30 mm. Clinically significant TRE reductions were also observed in head repositioning and static force testing experiments. Conclusions: The granular jamming cap concept increases the robustness and accuracy of image guided sinus and skull base surgery by more firmly attaching fiducial markers to the patient's skull.

Submitted Abstracts

12. Combined in silico and in vitro approach predicts low WSS regions that correlate with thrombus formation in vivo

Amanda K. W. Buck [Department of Radiology and Radiological Sciences (VUMC); Vanderbilt University Institute of Imaging Sciences (VUMC); Department of Biomedical Engineering (VU)]; Joseph J. Groszek [Nephrology and Hypertension (VUMC)]; Sara B. Keller [Biomedical Engineering Department (University of Washington)]; Daniel Colvin (Vanderbilt University Institute of Imaging Science (VUMC); Department of Radiology and Radiological Sciences (VUMC)]; Clark Kensinger [Department of Surgery (VUMC)]; Rachel Forbes [Department of Surgery (VUMC)]; Seth Karp [Department of Surgery (VUMC)]; Phillip Williams [Department of Surgery (VUMC)]; Shuvo Roy [Department of Bioengineering & Therapeutic Sciences (University of California San Francisco)]; William H. Fissell [Nephrology and Hypertension (VUMC)]

Chronic kidney failure is associated with significant physical and financial burden. Renal transplant, while superior to dialysis with regard to survival, cost, and overall burden of care for patients with chronic kidney failure, is limited by a paucity of donation organs. To overcome this scarcity problem, our team is using a two-stage approach to develop a bioartificial kidney using a silicon hemofilter and renal tubule bioreactor. A major challenge in developing blood-contacting medical devices is mitigating thrombogenicity. Thrombi may interfere with device function or embolize from the device to occlude distant vascular beds with catastrophic consequences. Here, an iterative approach to blood flow path design incorporating in silico, in vitro, and in vivo experiments was employed to identify potential fluid dynamics contributors to thrombogenicity in an implantable hemofilter design under realistic operating conditions and to guide design revisions. Computational fluid dynamics (CFD) models were validated using magnetic resonance imaging of flow through the device in vitro. Physiologic CFD simulations predicted regions of pervasive low wall shear stress that correlated with clot formation in vivo (four of five devices revealed clots upon explant). Subsequently refined hemofilter models demonstrated improved performance in vivo with no clot formation in explanted devices (n=6). The results demonstrate both the feasibility and the utility of a combined approach in developing intra-vascular, bioartificial, organ-replacement devices.

13. Determining Surgical Variables for a Brain Shift Correction Pipeline using an Android application

Rohan C. Vijayan [1], Reid C. Thompson [2,4], Lola B. Chambless [2], Peter J. Morone [2], Le He [2], Logan W. Clements [1,4], Rebekah C. Griesenauer [1,4], Michael I. Miga [1,2,3,4]

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The fidelity of image-guided neurosurgical procedures is often compromised due to the mechanical deformation that the brain experiences as a result of mechanical and physiological effects that occur during surgery. In recent work, a computational pipeline was developed to predict the extent of this brain shift in brain-tumor resection procedures. The pipeline uses preoperatively determined surgical variables (such as head orientation) to predict brain shift, and then subsequently correct guidance systems by manipulating the patient's preoperative image volume to more closely match the intraoperative state of the patient's brain. However, a clinical workflow difficulty with the execution of this pipeline is the preoperative acquisition of surgical variables. In order to simplify and expedite this process, an Android, Java-based application was developed for tablets to provide neurosurgeons with the ability to manipulate 3D models of the patient's neuroanatomy and determine an expected head orientation, craniotomy size and location, and trajectory to be taken into the tumor. These variables can then be exported for use as inputs to the biomechanical models of the brain shift correction pipeline. The app's accuracy was assessed by comparing variables created by four surgeons for five cases on the app to the variables created by the same surgeons for the same cases in a physical mock procedure on a mannequin head. It was concluded that the Android application was an accurate, efficient, and timely method of planning surgical variables.

Submitted Abstracts

14. Development of a Speculum-Free Optical Assessment Device for Use in Obstetric Care

Katherine Cochran (Engineering Science), Christine M. O'Brien (Biomedical Engineering), Jennifer Thompson (Obstetrics & Gynecology), Mack Goldberg (Obstetrics & Gynecology), J. Michael Newton (Obstetrics & Gynecology), Kelly A. Bennett (Obstetrics & Gynecology), Jeff Reese (Pediatrics), Anita Mahadevan-Jansen (Biomedical Engineering)

Preterm labor is responsible for one million deaths a year and is a risk factor in over half of all neonatal deaths, yet current predictive measures are limited in sensitivity. Spontaneous preterm labor is always preceded by the poorly-understood cervical remodeling process, and quantitative analysis of this process could lead to a better understanding of why and how the process is triggered too early in preterm labor. In this project, Raman spectroscopy was evaluated for use as a quantitative method to detect biochemical changes in the cervix in vivo in efforts to find a clinical tool for detection of patients at risk of preterm labor and delivery. Raman technology was found to be sensitive to cervical ripening and predictive of remaining time to delivery in a cohort of 10 patients in labor. However, the technology currently requires the use of a speculum exam to clean and visualize the tissue. Because of the clinical impracticality and physical discomfort associated with with a speculum exam, it is crucial that a new, speculum-free version of the technology be developed. A prototype for a speculum-free optical device was developed and incorporates components that allow for visualization of the cervix, cleaning of the cervix, displacement of vaginal tissue for line-of-sight access to the cervix, and collection of optical data.

15. Development of a Wide-field Near-Infrared Autofluorescence Imaging System for Surgical Guidance During Soft Tissue Sarcoma Resections

John Quan Nguyen, Giju Thomas, Ginger E. Holt, Anita-Mahadevan Jansen
*Biomedical Engineering

Soft Tissue Sarcomas (STS) are a rare and heterogeneous group of malignant tumors that are primarily treated through surgical resection and radiation. For these procedures, a positive surgical margin is the greatest predictor of local recurrence. However, margin statuses following STS resections are often determined weeks following the procedure. Current intraoperative biopsy methods are time consuming, delays patient care, and indicates the need for a rapid and accurate tool that can provide surgeons with immediate feedback during an operation. Recently our lab has demonstrated the potential of near-infrared (NIR) autofluorescence and Raman spectroscopy for providing differential diagnoses of in vivo STS and surrounding normal tissues through the use of a probe based spectroscopy system. Here, we present an expansion upon this work in which we are currently developing a wide-field NIR autofluorescence imaging system capable of interrogating a 15 cm2 surface area with a spatial resolution of 250 µm. The system and complimentary software is designed to automatically map suspicious tumor margins during an operation and convey their locations to surgeons via a projection overlay. The development of this technique would allow for the intraoperative detection of residual STS margins and could reduce the incidence of inadequate tumor excisions. This would prevent the need for multiple surgeries and lower the risk of surgical complications for this patient population.

Submitted Abstracts

16. Development of an Optically-guided System for Transcranial Ultrasound Neuromodulation

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Introduction: Focused ultrasound is a promising method for non-invasive neural stimulation therapies in the brain. Early animal and human studies have shown that neurological conditions such as essential tremors can be effectively treated with ultrasound ablation therapy, while sub-thermal neuromodulation has therapeutic effects that could benefit a variety of neurological diseases, including manic depressive disorder, Alzheimer's and epilepsy. Ultrasound treatments typically occur using image-guidance within a magnetic resonance imaging (MR) system, but working outside the MR environment is often desirable. Conventional image-guided surgery can be used to enable ultrasound neurosurgery outside the magnet by using preoperative MR data registered to the physical patient, fixing tracked markers to the ultrasound probe and registering the tracked space to pre-acquired images. The accuracy of this system is determined by calibration between the tracked markers and acoustic focus. Here, we present a pulse-echo based method of calibration and characterize its accuracy using MR thermometry.

Results and Discussion: MRI (green stars) and optically tracked fiducials (red triangles) were registered to coincident locations (Figure 1b), yielding a fiducial registration error of 2.8 mm. After registration, the mean TRE between the pulse-echo focus and thermal focus across three phantoms was 5.7 +/- 1.5 mm (Figure 1c). This error is comparable to published methods, but work is ongoing to achieve better results by optimizing placement of optical tracking targets on the HIFU transducer. The TRE of this method in the context of trans-cranial sonication is currently being evaluated.

Submitted Abstracts

17. Don't Get Burned: Thermal Monitoring of Vessel Sealing using a Miniature Infrared Camera

Shan Lin [1], Loris Fichera [2], Mitchell Fulton [2.3], Robert J. Webster III [2]

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Recently miniature chip-tip infrared cameras have come to market for industrial applications that have a form factor that facilitates packaging in endoscopic or other minimally invasive surgical instruments. If absolute temperature measurements can be made with these cameras, they may be useful for non-contact monitoring eletrocautery-based vessel, or other thermal surgical processes like thermal ablation of tumors. As a first step in evaluating the feasibility of optical medical thermometry with these new chip tip cameras, in this paper we explore how well thermal measurements can be made with them. These cameras measure the raw flux of incoming IR radiation, and we perform a calibration procedure to map their readings to absolute temperature values in the range between 40 and 150 °C.

18. Emulation of the laparoscopic environment for image-guided liver surgery via an abdominal phantom system with anatomical ligamenture

Jon S. Heiselman [1], Jarrod A. Collins [1], Jared A. Weis [1], Logan W. Clements [1], Amber L. Simpson [2], Sunil K. Geevarghese [3,4], William R. Jarnagin [2], and Michael I. Miga [1,4,5,6]

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In order to rigorously validate techniques for image-guided liver surgery (IGLS), an accurate mock representation of the intraoperative surgical scene with quantifiable targets would be highly desirable. However, many attempts to reproduce the laparoscopic environment have encountered limited success due to neglect of several crucial design aspects. The laparoscopic setting is complicated by factors such as gas insufflation of the abdomen, changes in patient orientation, incomplete organ mobilization from ligaments, and limited access to organ surface data. The ability to accurately represent the influences of anatomical changes and procedural limitations is critical for appropriate evaluation of IGLS methodologies such as registration and deformation correction. However, these influences have not yet been comprehensively integrated into a platform usable for assessment of methods in laparoscopic IGLS. In this work, a mock laparoscopic liver simulator was created with realistic ligamenture to emulate the complexities of this constrained surgical environment for the purposes of realizing laparoscopic IGLS. The mock surgical system reproduces an insufflated abdominal cavity with dissectible ligaments, variable levels of incline matching intraoperative patient positioning, and port locations in accordance with surgical protocol. True positions of targets embedded in a tissue-mimicking phantom are measured from CT images. Using this setup, image-to-physical registration accuracy was evaluated for simulations of both right and left lobe hepatectomy to assess rigid registration performance under more realistic laparoscopic conditions. Preliminary results suggest that nonrigid organ deformation and the extent of organ surface data collected affect the ability to attain highly accurate registrations in laparoscopic applications.

Submitted Abstracts

19. Evaluating a clinical prototype for label-free rapid intra-operative parathyroid detection

Giju Thomas [1], Melanie A. McWade [1], Emmanuel A. Mannoh [1], Melinda E. Sanders [2], James T. Broome [3], Carmen C. Solórzano [4], Anita Mahadevan-Jansen [1]

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Objective: Identifying parathyroid tissues during thyroid and parathyroid surgeries is challenging and may require frozen biopsies, that are labor intensive and time-consuming. This study aims for translating a near-infrared (NIR) autofluorescence detection system into a user-friendly clinical prototype for rapid real-time intra-operative parathyroid identification without using fluorescent dyes/labels. Method: A research-grade system initially measured tissue NIR autofluorescence for real-time parathyroid identification in vivo in 154 patients undergoing thyroidectomy and/or parathyroidectomy. Based on the same principle, this system was translated into a user-friendly clinical prototype called PTEye, designed to function with the operation room (OR) lights turned on. PTEye was then tested in 30 patients with 170 parathyroid, 95 thyroid, 56 muscle, 56 fat and 56 tracheal measurements. Accuracy was determined by correlating the acquired data with (1) visual confirmation by surgeon for unexcised parathyroids or (2) frozen biopsy report for excised parathyroids. Results: The research-grade system achieved 95.4% sensitivity and 96.9% specificity in detecting parathyroids with OR lights off, while PTEye identified parathyroids with 99.4% sensitivity and 95.2% specificity, despite ambient OR lights. Both systems identified parathyroids in real-time, regardless of its diseased/normal state. Conclusion: We were able to successfully translate a research-grade detection system from 'bench-to-bedside' as a clinical prototype 'PTEye' for real-time label-free parathyroid identification with high accuracy inside the OR. The intuitive interface of PTEye and its ability to rapidly detect parathyroid with ambient OR lights can ensure easy usability by endocrine surgeons.

Submitted Abstracts

20. Evaluation of a high-resolution patient-specific model of the electrically stimulated cochlea

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Cochlear implants (CIs) are considered standard treatment for patients who experience sensorineural hearing loss. Although these devices have been remarkably successful at restoring hearing, it is rare to achieve natural fidelity, and many patients experience poor outcomes. Our group has developed the first image-guided CI programming (IGCIP) technique where the positions of the electrodes are found in CT images and used to estimate neural activation patterns, which is unique information that audiologists can use to define patient-specific processor settings. In our current system, neural activation is estimated using only the distance from each electrode to the neural activation sites. This approach might be less accurate than using a high-resolution electro-anatomical model (EAM) of the electrically stimulated cochlea to perform physics-based estimation of neural activation. In this work, we propose a patient-customized EAM approach where the EAM is spatially and electrically adapted to a patient-specific configuration. Spatial adaptation is done through non-rigid registration of the model with the patient CT image. Electrical adaptation is done by adjusting tissue resistivity parameters so that the intra-cochlear voltage distributions predicted by the model best match those directly measured for the patient via their implant. We demonstrate our approach for N=7 patients. We found that our approach results in mean percent differences between direct and simulated measurements of voltage distributions of 11%. In addition, visual comparison shows the simulated and measured voltage distributions are qualitatively in good agreement. This represents a crucial step toward developing and validating the first in vivo patient-specific cochlea EAMs.

Submitted Abstracts

21. *Ex Vivo* Rat Aorta Radial Overstretch Inhibits Smooth Muscle Contractility

Kameron V. Kilchrist [1]; Christy M. Guth [2]; Joyce Cheung-Flynn [2]; Colleen M. Brophy [3]; Craig L. Duvall [1]

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Vascular radial overstretch injury results from mismatch of angioplasty balloon diameter to vessel diameter when treating vascular disease. Despite initial patient improvement, frequently vessels undergo restenosis due to smooth muscle cell proliferation. In vivo models of this pathology are challenging in rodents due to size constraints, therefore we have begun to develop a model of ex vivo radial overstretch injury to induce pathologic tissue responses to screen biomaterial enabled biologic drug delivery interventions.

Rat aortas were harvested with a minimal touch technique, laterally bisected into control and experimental groups, and distended to predetermined diameters with coronary angioplasty balloons ex vivo. After distention, tissue was sectioned into rings and randomly assigned to physiology or tissue culture groups. To assess tissue physiology, aortic rings were immediately hanged between a fixed post and a force transducer. Stress generation was measured to assess tissue contractility and vasorelaxivity. The rings assigned to tissue culture were maintained in high serum conditions for five days and processed as tissue microarrays by immunohistochemistry.

Preliminary results show that radial overstretch but not understretch induces loss of contractility. Both stretch conditions show functional impairment in endothelial function. In culture, both groups show increases in collagen IV, vimentin, and Ki67 expression, and a loss of smooth muscle actin expression.

The further characterization of this radial overstetch model will allow the exploration of tissue biomechanics and the relationship between tissue biomechanics, physiology, and cellular phenotype. This model shows promise as an ex vivo model of damaged vasculature that can be used to interrogate the effects of multiple gene and kinase regulatory pathways, addressing a critical gap between high throughput in vitro and low throughput in vivo studies.

Submitted Abstracts

22. Focused Stimulation of Dorsal Subthalamic Nucleus Improves Reactive Inhibitory Control of Action Impulses

van Wouwe, N.C. [1], Pallavaram, S. [3], Phibbs, F. [1], Martinez-Ramirez, D. [4], Neimat, J.S. [2], Dawant, B.M. [3], D'Haese, P.F. [3], Kanoff, K.E. [1], van den Wildenberg, W.P.M. [5], Okun, M.S. [4], & Wylie, S.A. [2]

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Frontal-basal ganglia circuitry dysfunction caused by Parkinson's disease impairs important executive cognitive processes, such as the ability to inhibit impulsive action tendencies. Subthalamic Nucleus Deep Brain Stimulation in Parkinson's disease improves the reactive inhibition of impulsive actions that interfere with goal-directed behavior. An unresolved question is whether this effect depends on stimulation of a particular Subthalamic Nucleus subregion. The current study aimed to 1) replicate previous findings and additionally investigate the effect of chronic versus acute Subthalamic Nucleus stimulation on inhibitory control in Parkinson's disease patients off dopaminergic medication 2) test whether stimulating Subthalamic Nucleus subregions differentially modulate proactive response control and the proficiency of reactive inhibitory control. In the first experiment, twelve Parkinson's disease patients completed three sessions of the Simon task, Off Deep brain stimulation and medication, on acute Deep Brain Stimulation stimulation and on chronic Deep Brain Stimulation stimulation. Experiment 2 consisted of 11 Parkinson's disease patients with Subthalamic Nucleus Deep Brain Stimulation (off medication) who completed two testing sessions involving of a Simon task either with stimulation of the dorsal or the ventral contact in the Subthalamic Nucleus. Our findings show that Deep Brain Stimulation improves reactive inhibitory control, regardless of medication and regardless of whether it concerns chronic or acute Subthalamic Nucleus stimulation. More importantly, selective stimulation of dorsal and ventral subregions of the Subthalamic Nucleusindicates that especially the dorsal Subthalamic Nucleus circuitries are crucial for modulating the reactive inhibitory control of motor actions.

Submitted Abstracts

23. Force-Controlled Exploration for Updating Virtual Fixture Geometry In Model-Mediated Telemanipulation

Long Wang, Zihan Chen, Preetham Chalasani, Rashid M. Yasin, Peter Kazanzides, Russell H. Taylor and Nabil Simaan

Vanderbilt University and Johns Hopkins University

This paper proposes an approach for using force-controlled exploration data to update and register an a-priori virtual fixture geometry to a corresponding deformed and displaced physical environment. An approach for safe exploration implementing hybrid motion/force control is presented on the slave robot side. During exploration, the shape and the local surface normals of the environment are estimated and saved in an exploration data set. The geometric data collected during this exploration scan is used to deform and register the a-priori environmentmodel to the exploration data set. The environment registration is achieved using a deformable registration based on the coherent point drift method. The task-description of the high-level assistive telemanipulation law, called a virtual fixture (VF), is then deformed and registered in the new environment. The new model is updated and used within a model-mediated telemanipulation framework. The approach is experimentally validated using a da-Vinci research kit (DVRK) master interface and a Cartesian stage robot. Experiments demonstrate that the updated VF and the updated model allow the users to improve their path following performance and to shorten their completion time when the updated path following VF is applied. The approach presented has direct bearing on a multitude of surgical applications including force-controlled ablation.

Submitted Abstracts

24. High-resolution whole-brain MR thermometry for transcranial focused ultrasound

Sumeeth Jonathan, M.S., Biomedical Engineering; William Grissom, Ph.D., Biomedical Engineering

Real-time whole-brain MR thermometry is needed for transcranial MR-guided focused ultrasound to accurately track rapid heating at the focus and to monitor for unsafe heating in the near- and far-field. Previous efforts to meet this need have been based on 3D segmented echo planar imaging (EPI) and spiral MR readouts. We propose a novel 3D EPI stack-of-stars temperature mapping pulse sequence that enables greater volume coverage than has been reported with previous approaches. The sequence allows flexible adjustment of the scan acceleration factor and does not require a high density of receive coils for high frame rate thermometry.

Submitted Abstracts

25. How often do cochlear implants move after implantation?

Yiyuan Zhao [1], Jack H. Noble [1], Benoit M. Dawant [1], Robert F. Labadie [2]

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Hypothesis: Cochlear implants (CI) may show clinically significant migration over time Background: CIs are neural prosthetic that provide a sense of hearing to people having severe to profound hearing loss. Both CI electrode array and internal receiver locations are typically assumed to be stable after implantation. Using a large CI imaging database we retrospectively evaluated how often CI electrodes and internal receiver migrate.   Methods: From an IRB-approved database of 303 CI patient CT scans, we identified ten patients with at least two post-implant CTs. In the scans, the center of each contact was identified using previously published image processing algorithms. The two CTs were then fused and electrode migration quantified by calculating the Euclidean distance between corresponding electrodes in the sequential scans. Visual assessment of alignment of the internal receivers in the fused image was used to determine if clinically significant migration had occurred.   Results: Time between scans averaged 615.2 days (range 84-1565 days). The median and mean±standard deviation of the distances between corresponding electrodes was 0.22 and 0.58±1.07mm. In all but 1 patient, distances approached the limits of CT resolution rather than representing clinically significant migration. Only one patient had appreciable electrode migration (3.61±0.92mm) and obvious internal receiver migration over 602 days between scans.   Conclusion: While a limited dataset, using well validated image processing techniques we have shown that 1 of 10 patients had clinically significant CI motion over time without obvious reason (e.g. no MRI, no head trauma), and, perhaps more importantly, that 9 of 10 did not.

26. Image-based Mathematical Modeling to Differentiate Radiation-Induced Necrosis from Tumor Recurrence Following Stereotactic Radiosurgery for Intracranial Metastasis.

Jared A. Weis, Nitesh Rana, Michael I. Miga, Reid C. Thompson, Kyle D. Weaver, Lola B. Chambless, Anthony J. Cmelak, Albert Attia

Department of Biomedical Engineering — Vanderbilt University, Nashville TN.
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Patients with intracranial metastasis treated with stereotactic radiosurgery are often evaluated for local control using serial MRI with T1 post-contrast and FLAIR imaging. It is difficult to distinguish local recurrence from radiation-induced necrosis, as both demonstrate expanding areas of enhancement and surrounding FLAIR abnormality. We hypothesize that developments in image-based modeling of tumor growth can be extended to differentiate the etiology of enhancing lesions. In preliminary analysis, we evaluated serial imaging from patients with radiation-induced necrosis or tumor recurrence. A reaction-diffusion logistic growth model was used to extract tumor growth and diffusion parameters based on fitting areas of post-contrast T1 enhancement. The model also allows calculation of mass effect incurred during lesion expansion. All clinically-available imaging time points between SRS and clinical decision for resection were selected for analysis. Diagnosis of tumor recurrence or radiation-induced necrosis was verified histologically. Initial observations of the estimated tumor cell proliferation rate reveals significant differences between necrotic and recurrent lesions. Clear differences are also observed when comparing the model-calculated mechanical stress field with edema visualized from FLAIR imaging. Recurrent lesions exhibit an estimated mechanical stress field with a compelling degree of correlation to the measured FLAIR images at each time point compared to radiation-induced necrosis lesions. Preliminary results indicate the considerable promise for a biophysical mathematical model-based analysis in predicting and differentiating radiation-induced necrosis from tumor recurrence. If confirmed, this approach could have clear implications for accurate/noninvasive determination of post-SRS enhancing lesion etiology, reducing costs due to unnecessary imaging or missed diagnosis.

Submitted Abstracts

27. Image-guided feedback for ophthalmic microsurgery using multimodal intraoperative swept-source spectrally encoded scanning laser ophthalmoscopy and optical coherence tomography

Jianwei D. Li [1], Joseph D. Malone [1], Mohamed T. El-Haddad [1], Karen M. Joos [1,2], Shriji N. Patel [2], and Yuankai K. Tao [1]

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Surgical interventions for ocular diseases involve manipulations of semi-transparent structures in the eye, but limited visualization of these tissue layers remains a critical barrier to developing novel surgical techniques and improving clinical outcomes. We addressed limitations in image-guided ophthalmic microsurgery by using microscope-integrated multimodal intraoperative swept-source spectrally encoded scanning laser ophthalmoscopy and optical coherence tomography (iSS-SESLO-OCT). We previously demonstrated in vivo human ophthalmic imaging using SS-SESLO-OCT, which enabled simultaneous acquisition of en face SESLO images with every OCT cross-section. Here, we integrated our new 400 kHz iSS-SESLO-OCT, which used a buffered Axsun 1060 nm swept-source, with a surgical microscope and TrueVision stereoscopic viewing system to provide image-based feedback. In vivo human imaging performance was demonstrated on a healthy volunteer, and simulated surgical maneuvers were performed in ex vivo porcine eyes. Densely-sampled static volumes and volumes subsampled at 10 volumes-per-second were used to visualize tissue deformations and surgical dynamics during corneal sweeps, compressions, and dissections, and retinal sweeps, compressions, and elevations. En face SESLO images enabled orientation and co-registration with the widefield surgical microscope view while OCT imaging enabled depth-resolved visualization of surgical instrument positions relative to anatomic structures-of-interest. TrueVision heads-up display allowed for side-by-side viewing of the surgical field with SESLO and OCT previews for real-time feedback, and we demonstrated novel integrated segmentation overlays for augmented-reality surgical guidance. Integration of these complementary imaging modalities may benefit surgical outcomes by enabling real-time intraoperative visualization of surgical plans, instrument positions, tissue deformations, and image-based surrogate biomarkers correlated with completion of surgical goals.

Submitted Abstracts

28. Imaging in the Optic Nerve: Insights into Optic Nerve Pathology

Robert L Harrigan [1], Shikha Chaganti [2], Alex K. Smith [3], Charles Olivier [1], Katrina Nelson [1], Stephen M. Damon [1], Bailey D. Lyttle [3], Kunal P. Nabar [2], Naresh Nandakumar [1], Siddharama Pawate [4], Tony Capra [7], Daniel Fabbri [7], Seth A. Smith [3,5,6], Louise A. Mawn [6], Bennett A. Landman [1,2,5]

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Millions of Americans suffer from Pathologies of the Human eye, Orbit and The Optic Nerve (PHOTON) such as glaucoma, multiple sclerosis, thyroid eye disease, and idiopathic optic neuritis. These diseases severely impact the quality of an individual's life. Yet, we do not have a reliable means to assess the risk of the disease in early stages, which is valuable to preventing loss of visual function. We are implementing a large-scale, image processing and data analytics study over multiple cohorts of diseases of the human eye, orbit and the optic nerve, with the ultimate goal of understanding early disease stages, enable timely intervention, and improve disease management. In a pilot study, we are investigating structural-functional phenotype associations. A principal component analysis (PCA) of the structural metrics over the thyroid eye disease patient cohort identifies two major phenotypes of the disease. We are developing new MRI sequences to image the optic nerve and enable new types of analyses. We compare radii of the optic nerve and surrounding cerebrospinal fluid (CSF) sheath along the entire length of the nerve between MS patients with and without a history of optic neuritis.

29. Improving Biomechanical/Biotransport Modeling of the Brain by Enhancing Anatomical Structures

Saramati Narasimhan [1], Michael I. Miga [1,2,3,4], Jared A. Weis [1,2], Reid C. Thompson [3]

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Elevated intracranial pressure (ICP) is a relatively common complication arising from central nervous system disorders, head trauma, stroke, and hydrocephalus. It is hypothesized that incorporating more detailed neuroanatomy within biotransport simulations is an important need for predicting biomechanical reactions to ICP-brain altering disorders. As a preliminary concept study, we wanted to simulate interstitial fluid flow from a pressure infusion source to facilitate comparisons of varying levels of enhanced neuroanatomical modeling. Specifically, the brain was modeled as (1) a completely homogeneous material, (2) a homogeneous tissue model with the addition of dural septa, and (3) as a homogeneous tissue model with dural septa, Sylvian fissure, and central sulcus. These latter two simulations serve as anatomical barriers to interstitial fluid flow. All three of the simulations used Biot's consolidation theory to describe the brain which describes the tissue as a fluid-saturated porous media. The model assumes linear-elastic, isotropic behavior for the solid matrix and that the fluid flows in the interstitium according to Darcy's law. The method of solution employed to resolve the partial differential equations was the Galerkin Method of Weighted Residuals expressed on tetrahedral finite elements and represents a steady-state solution. To simulate the effect of these barriers to flow, a pressure source, representative by a catheter, was introduced into all three simulations using a Dirichlet boundary condition with a specified hydraulic pressure. In the simulation without additional structures, the solution reflected pressure radiating symmetrically outward from the catheter. In the second simulation which introduced the dural septa, high pressure was confined to the hemisphere containing the catheter. The last simulation which introduced even more structural specificity with the Sylvian fissure, and central sulcus further constrained the movement of fluid, as reflected in the direction of flow around these structural fissures/folds separating tissue. The results of this preliminary study indicate that the incorporation of more detailed anatomical constraints could potentially have a significant impact on ICP distributions, and consequently flow within the interstitium, and that these structures should be included in further studies.

30. Informed Design of an External Stent to Prevent Dialysis Access Failure

Timothy C. Boire (Biomedical Engineering), Christy M. Guth (Vascular Surgery), Byron F. Smith (Mechanical Engineering), William C. Kaplan (Biomedical Engineering), Jae Han Lee (Biomedical Engineering), Nicolo Garbin (Mechanical Engineering), Addisu Z. Taddese (Mechanical Engineering), David Shaffer (Transplant Surgery), Brett Byram (Biomedical Engineering), Hak-Joon Sung (Biomedical Engineering), Haoxiang Luo (Mechanical Engineering), Colleen M. Brophy (Vascular Surgery)

Dialysis is the primary lifeline for patients with end-stage renal disease (ESRD). Unfortunately, 42% of dialysis grafts fail within the first 6 months, hampering the quality and length of life for patients. Financial repercussions, even when only considering the graft population, are also significant, resulting in $1.1 - 1.7 billion in direct costs that are primarily absorbed through the Centers for Medicare & Medicaid Services. Greater than 70% of these failures are the result of neointimal hyperplasia that is triggered by surgical trauma, wall shear stress gradients, turbulence, and many other factors. Therapeutic approaches to robustly prevent vein failures remain elusive, with a handful of other external stent approaches exhibiting initial promise before underachieving or failing in the clinic. Improper biomaterial selection and scaffold design and an apparent lack of device optimization are a big part of the problem. Our team is working to develop an external stent from shape memory polymers that can reduce dialysis access and vein graft failures by supplying durable, flexible, customized mechanical support around the critical anastomoses that are most prone to collapse and failure. It can also instantly wrap around the venous anastomosis without sutures, improving ease-of-use for surgeons. Here we present an overview of material properties, device fabrication, ex vivo perfusion chamber setup, and in vivo responses in a mouse subcutaneous model as a useful starting input to device optimization. Future optimization work involves the creation of a computational fluid dynamic model recapitulating the venous anastomosis, with validation in an ex vivo perfusion chamber.

31. Integrated System for Point Cloud Reconstruction and Simulated Brain Shift Validation Using Tracked Surgical Microscope

Xiaochen Yang [1], Logan W. Clements [2], Ma Luo [2], Saramati Narasimhan [2], Reid C. Thompson [3], Benoit M. Dawant [1,4], and Michael I. Miga [2,3,4]

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Intra-operative soft tissue deformation, referred to as brain shift, compromises the application of current image-guided surgery (IGS) navigation systems in neurosurgery. A computational model driven by sparse data has been used as a cost effective method to compensate for cortical surface and volumetric displacements. Stereoscopic microscopes and laser range scanners (LRS) are the two most investigated sparse intra-operative imaging modalities for driving these systems. However, integrating these devices in the clinical workflow to facilitate development and evaluation requires developing systems that easily permit data acquisition and processing. In this work we present a mock environment developed to acquire stereo images from a tracked operating microscope and to reconstruct 3D point clouds from these images. A reconstruction error of 1 mm is estimated by using a phantom with a known geometry and independently measured deformation extent. The microscope is tracked via an attached tracking rigid body that facilitates the recording of the position of the microscope via a commercial optical tracking system as it moves during the procedure. Point clouds, reconstructed under different microscope positions, are registered into the same space in order to compute the feature displacements. Using our mock craniotomy device, realistic cortical deformations are generated. Our experimental results report approximately 2mm average displacement error compared with the optical tracking system. These results demonstrate the practicality of using tracked stereoscopic microscope as an alternative to LRS to collect sufficient intraoperative information for brain shift correction.

Submitted Abstracts

32. Intraoperative Assessment of Parathyroid Gland Viability during Thyroid Surgery

Emmanuel A. Mannoh [1], Giju Thomas [1], Carmen C. Solorzano [2], Anita Mahadevan-Jansen [1]

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As many as 80,000 patients a year in the US undergo thyroidectomies or parathyroidectomies for diseased glands. About 21% of these surgeries result in disruption of blood supply to health parathyroid glands, which, if unaddressed, may result in long-term hypocalcemia. Surgeons need to know as soon as possible whether or not the blood supply to a parathyroid gland has been disrupted, as this informs their decision on whether or not to excise and reimplant the gland. There is a non-trivial failure rate involved in this transplantation process, and in the absence of an objective gold-standard for determining if a gland should be transplanted, surgeons often rely on subjective visual inspection. Here we present Laser Speckle Imaging as a real-time objective method to assess parathyroid gland viability. Our device consists of a 785 nm laser source and a near-infrared camera with a zoom lens, positioned above the surgical field with an articulated arm. With the laser diffusing light onto the tissue, the camera acquires images which are processed in real-time and displayed on a monitor. These speckle contrast images are then averaged and the relative difference in speckle contrast between the parathyroid gland and surrounding thyroid tissue is calculated and correlated with the surgeon's assessment of viability. Preliminary findings from in vivo measurement of 10 diseased glands show 100% agreement with the surgeon when taking a greater than 5% relative difference to indicate devascularization. This device has the potential to be used as an intraoperative tool for assessing parathyroid gland viability.

33. Low Rank plus Sparse Compressed Sensing Reconstruction for PRF Temperature Imaging

Zhipeng Cao, Sumeeth V. Jonathan, William A. Grissom

Department of Biomedical Engineering

A novel reconstruction method is developed to accelerate the proton resonance frequency (PRF) shift imaging for MRI, based on principles of low rank plus sparse compressed sensing and approximating PRF phase shift with complex difference. The method is demonstrated to be better than existing methods in three important applications: 1) monitoring of RF heating due to MRI, 2) MR-guided ultrasound ablation in the leg, and 3) water-bathed MR-guided ultrasound ablation in the brain. The result shows promising future of establishing more reliable safety guide line for high field MRI scanners, as well as better accuracy for MR-guided ultrasonic applications.

34. Medical Products Support Services

Medical Products Support Services, Center for Technology Transfer and Commercialization MPSS Team: Ken Holroyd, MD, MBA; Axel Strombergsson, M.Sc.; Lu Ellen Davie, MS, RN

The Medical Products Support Services (MPSS) was launched in May 2014, to assist engineers, physicians, scientists, and other faculty investigators who are working to bring innovative medical products out of their laboratories, and progress them toward the marketplace. MPSS is part of the Vanderbilt's Center for Technology Transfer and Commercialization (CTTC).   The MPSS team provides free assistance to Vanderbilt investigators in two areas: the Medical Device Regulatory Affairs Program (MDRAP), and the Medical Products Development and Commercialization Program (MPDCP). Learn more at www.cttc.co/mpss

Submitted Abstracts

35. On-Axis Acoustic-Radiation-Force-based Quantitative Stiffness Estimation in Phantoms

Kristy M. Walsh [1], Mark L. Palmeri [2], and Brett C. Byram [1]

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In shear wave elasticity imaging, stiffness can be estimated by measuring shear wave velocity at locations away from the acoustic radiation force (ARF) axis. Instead, this research estimates stiffness by measuring the time-to-peak displacement directly along the ARF axis, which reduces hardware and sequencing complexity. We have shown previously in simulation results that an advanced displacement estimator reduces variability in the final stiffness estimate. Here, we test the on-axis approach in 15 phantoms. We assume the phantoms are homogeneous, isotropic, and linearly elastic, thus time-to-peak displacement is directly proportional to shear wave speed. Since shear wave speed is directly related to shear stiffness, we created a stiffness look-up table of the time-to-peak displacement as a function of depth. We generated look-up tables using a 3D FEM model coupled to Field II simulations. Both normalized cross correlation (NCC) and Bayesian displacement estimators were evaluated. To evaluate the error of the on-axis method as compared to traditional shear wave methods, we computed a robust lateral time-of-flight-based shear wave speed and converted to a shear modulus for each phantom. The 15 phantoms had a mean shear modulus of 2.07 kPa and standard deviation of 0.12 kPa. We took the root mean square error of the shear modulus estimated using either the Bayesian displacement estimator or the NCC-derived estimator. In the depth of field, the median RMSE of shear modulus for the Bayesian estimator was 0.46 kPa and 0.93 kPa for NCC. These phantom results show that on-axis methods coupled with a Bayesian displacement estimator produce stiffness estimates comparable to laterally offset shear wave methods.

Submitted Abstracts

36. Optimizing breast cancer treatment regimens with Raman Spectroscopy

Giju Thomas [1], The-Quyen Nguyen [1,4], Isaac J. Pence [1], Brittany Caldwell [1], Fuyao Chen [1], Maggie Elizabeth O'Connor [1], Jennifer Giltnane [2], Melinda E. Sanders [2], Mark Kelley [3], Ana Grau [3], Ingrid Meszoely [3], Mary Hooks [3], and Anita Mahadevan-Jansen [1]

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Breast cancer (BC) mortality results in an estimated 40,000 deaths annually, making this the second leading cause of cancer death in American women. This results from (i) the inability to minimize BC recurrence following surgery and (ii) failing to start the most appropriate anti-BC therapies on time for patients. In this work, we propose to address these challenges by exploiting the potential of Raman spectroscopy (RS), which is sensitive to subtle tissue biochemical changes. We aim to test the hypothesis that RS can aid in minimizing BC recurrence, by determining accurately if the excised breast tumor margins are tumor-free or not in real-time (ii) RS can assess the tumor biochemical profile and help predict tumor prognosis, such as tumor invasiveness or drug resistance. For evaluating tumor margins, we applied Spatially Offset Raman Spectroscopy (SORS), a derivative of RS that can obtain depth-resolved tissue biochemical information up to 2mm deep. SORS was applied on tumor specimens from 30 BC patients, that included 122 tumor negative and 20 tumor positive margins confirmed by histopathology. SORS could differentiate between positive and negative margins with an overall accuracy of 77.5%. This technique was augmented by developing a 3-Dimensional SORS based scanner that was tested in five mastectomy specimens. The device could scan breast specimen margins in 3D, and allow direct correlation of tumor-positive margins in the patient in-situ. For understanding tumor prognosis, we are evaluating RS spectra of different BC cell-lines grown on biocompatible stainless steel plates.

Submitted Abstracts

37. Orientation-independent z-shimmed temperature mapping near ablation probes

Megan E Poorman (Biomedical Engineering, Institute of Imaging Science)
William A Grissom (Biomedical Engineering, Institute of Imaging Science)

MR guidance of thermal ablation is hindered by signal loss around the metallic applicators and needles used to deliver treatment. This loss of MRI signal can prevent accurate MR thermometry in the area of critical heating near ablation probe. Many modern RF ablation probes incorporate a thermocouple for real-time feedback of information, however this temperature information is not spatially resolved. Particularly in cases where the target region is less than a centimeter in diameter, such as RF ablation of epilepsy, accurate and spatially resolved temperature information near the probe is critical in assessing treatment margins. There is a need for an MR thermometry method that can recover temperature information near metal ablation probes, regardless of probe or slice orientation within the magnetic field. Here we present a multiple-echo z-shimmed sequence that can correct for through-plane distortion from the probe irrespective of probe and slice orientations. The sequence recovers the through-slice gradient caused by the probe using a slice refocusing gradient of varying percentage of the full refocusing area on each echo. A refocusing scheme optimization technique was developed and, when implemented on the scanner, the optimized z-shimmed sequence resulted in a near-probe signal recovery ratio of 10 to 1 in perpendicular slices and 6.5 to 1 in parallel slices. Temperature maps reconstructed from z-shimmed images showed a lower temperature standard deviation near the probe than conventional single echo thermometry. This method is applicable regardless of probe and slice orientations and can be performed with minimal setup optimization.

38. Perception of Navigation Information from a 3-D Image Guidance System for Open Hepatic Surgery

Logan W. Clements [1], Amber L. Simpson [2], Jarrod A. Collins [1], Jared A. Weis [1], Jon S. Heiselman [1], T. Peter Kingham [2], Willam R. Jarnagin [2], and Michael I. Miga [1]

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While 3-D image-guided surgery has been a valuable adjunct to surgeons across numerous procedures, guidance information in commercially available systems can be compromised due to inherent rigid body assumptions. In this work we seek to determine the ability of surgeons to perceive improvement in guidance information when a model-based registration method is compared with traditional rigid registration methods. A series of 125 registration evaluations were performed across 20 patients at the Memorial Sloan-Kettering Cancer Center. The registration evaluation involved the comparison of the two registrations displayed to the clinician in a psuedo-random and blinded order. For all cases, the traditional rigid registration was evaluated initially during the period in which the model-based correction result was computed. The evaluation began by displaying either the rigid or model-based registration and the clinician provided a rating (R) of the guidance accuracy improvement or degradation over the previously displayed registration on an integer scale from -3 to +3. In general, the registration evaluation process involved a survey of the guidance information displayed by the system as the clinician moved an optically tracked probe across the liver surface. A statistical analysis of the series of clinician rating data indicates that the surgeons were able to perceive a statistically significant ($p = 0.01$) improvement (defined as a $R > 1$) of the model-based registration over the rigid registration as well as a statistically significant ($p = 0.03$) degradation (defined as $R < -1$) when the rigid registration was compared with the model-based guidance information.

Submitted Abstracts

39. Perfusion Imaging with Non-Contrast Ultrasound

Jaime Tierney (VU BME), Crystal Coolbaugh (VU Radiology and Radiological Sciences and VUIIS), Theodore Towse (VU Physical Medicine and Rehabilitation), and Brett Byram (VU BME)

Conventional Doppler ultrasound is useful for visualizing fast blood flow in large resolvable vessels. However, frame rate and tissue clutter caused by movement of the patient or sonographer make visualizing slow flow with ultrasound difficult. Patient and sonographer motion results in spectral broadening of the clutter signal, which limits ultrasound's sensitivity to velocities greater than 5-10mm/s for typical clinical imaging frequencies. To address this, we propose a clutter filtering technique that may increase the sensitivity of Doppler measurements to at least as low as 0.62mm/s. The proposed technique uses plane wave imaging and an adaptive frequency and amplitude demodulation scheme to decrease the bandwidth of tissue clutter. To test the performance of the adaptive demodulation method at suppressing tissue clutter bandwidths due to sonographer hand motion alone, six volunteer subjects acquired data from a stationary phantom. Additionally, to test in vivo feasibility, a muscle contraction study was performed to assess the efficiency of the proposed filter at preserving signals from blood velocities 2mm/s or greater at a 7.8MHz center frequency. The hand motion study resulted in initial average bandwidths of 220Hz (10.8mm/s), which were decreased to 12.6Hz (0.62mm/s) at -60dB using our approach. The in vivo power Doppler study resulted in 4.80dB and 0.16dB dynamic ranges of the blood flow with the proposed filter and a conventional 50Hz high pass filter, respectively.

Submitted Abstracts

40. Predicting the Response of Triple Negative Breast Cancer to Doxorubicin

Matthew T. McKenna [1,2], Jared A. Weis [2], Stephanie L. Barnes [3,8], Darren Tyson [4], Michael I. Miga [2,5], Vito Quaranta [4], Thomas E. Yankeelov [3,7,8,9]

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Introduction The goal of this study is to establish a data-driven model of cytotoxic therapy that predicts in vitro cell population dynamics in response to a single time-resolved doxorubicin dose. Experimental Design SUM-149PT cells were seeded in microtiter plates and allowed to reach a steady proliferation rate. Doxorubicin was introduced at concentrations ranging from 10 nM to 2.5 μM and subsequently removed via media replacement after 6, 12, or 24 hours. These cells were imaged and counted daily for 25 days following application of doxorubicin. A logistic growth model modified by a set of time-dependent growth functions was employed for this study. A leave-one-out approach was employed to predict population changes following treatment at new concentrations and exposure times. Results Higher doses of doxorubicin (>1 μM) induced rapid cell death. Smaller doses (<1 μM) induced a concentration-dependent nonlinear response defined by an initial increase in population size that, depending on exposure time, was followed by a protracted decrease in cell number and subsequent regrowth of the population. The mean percent error of the best-fit model across all treatment conditions was 12.4 (±11.0) while the mean percent error of the predicted models was 14.9 (±13.0). Conclusion These time-resolved treatment protocols replicate the clinically observed pharmacokinetics of cytotoxic therapies more closely than the constant concentrations in previous dose-response assays. With this data-rich approach, the in vitro response of a triple negative breast cancer cell line to doxorubicin can be predicted. This approach should allow for predictions of tumor response in animal models.

Submitted Abstracts

41. Prediction of chronological age from hierarchical brain volumes using a random forest regression can provide a personalized lifetime metric of aging.

Camilo Bermudez (BME) Yuankai Huo (EE) Andrew Plassard (CS) Katherine Aboud (Neuroscience) Laurie Cutting (Peabody) Bennett Landman (EE)

Understanding how brain volumes change over time provides insight into development, aging, and disease. Age-related changes have been studied in detail for specific age ranges, e.g. during early life for neurodevelopmental disorders and late life for Alzheimer's Disease, but a normative description of volume change over the human lifetime has been less well described. Recent advances in the sharing and processing of large data sets have allowed access to many brain images of normal, healthy volunteers in order to perform a large-scale cross-sectional analysis across the lifetime. Using an established hierarchy of brain structure, we seek to understand how groups of brain regions can predict age at different developmental time points. To capture nonlinear changes, we propose random forest regression prediction of age based on multi-variate, hierarchical brain volumes alongside categorical demographic variables of gender and handedness. We derived a predictive age model using imaging from 4575 healthy patients from 60 sites and spanning ages from 4 to 94. Preliminary results show age-prediction within a margin of ± 5 years during ages 4-30 and a margin of ± 10 years during ages 30-90. Volume-based age prediction provides a personalized analysis of brain morphology regardless of chronological age. This new metric can be compared to an age-matched population to describe individual aging or it can be compared to similar morphology populations to find patterns in disease or the effect of treatment. These results may also provide insight into how developmental networks grow together and their relative importance at different stages in life.

42. Real-time Identification of In-situ Pulmonary Nodule and Pathology Using Optical Coherence Tomography

Gilmore, DM; Thomas, G; Mahadevan-Jansen, A; Grogan, E

Vanderbilt University Medical Center, Department of Thoracic Surgery

Objectives: Due to lung cancer screening and increased use of CT scans, the incidence of indeterminate pulmonary nodules (IPN) and ground glass opacities (GGO) is increasing. In lesions requiring surgical biopsy, small (<1 cm) IPN may be difficult to localize in the OR using a minimally invasive approach. Optical Coherence Tomography (OCT) utilizes interference of light waves between different layers of tissues to provide high-resolution, cross-sectional images of the internal microstructure by measuring back-reflected light. This approach can deliver video rate images of tissue structure on the micron scale in situ and can be used to scan large areas of tissue to identify nodules and provide realtime histology-like images without actual removal of tissue to detect lung lesions. OCT may aid in the localization and diagnosis of malignant lesions in patients with IPN or GGO without utilization of potentially toxic dyes or radiation. Methods: Fifteen human lung tissue samples (5 malignant pathology, 5 benign pathology and 5 normal lung tissue) were obtained through an IRB approved protocol from the Cooperative Human Tissue Network thoracic oncology tissue biorepository. Tissue was fresh frozen, stored in -80C and analyzed using a 1310nm wavelength OCT system (Thorlabs Telesto, NJ). Each specimen was scanned with an area of 64-100 mm2 to a depth of 3.5mm. Image acquisition took less than one second for two dimensional and 20 seconds for three dimensional images. Specimens were analyzed by a blinded reviewer. Results: Among the 15 samples, 100% of normal lung tissue (5/5) produced low intensity, homogenous tissue patterns. 80% benign pathology (4/5) retained the homogenous pattern of normal tissue but with higher intensity signal. In contrast, 80% (4/5) malignant samples exhibited a heterogenous cauliflower like pattern at high intensity. Conclusions: Utilizing OCT, real-time localization of IPN and GGO within lung tissue as well as determination of pathology can be performed prior to resection. Further optimization of this technique by potentially combining OCT with other optical imaging methods such as fluorescence or Raman spectroscopy may aid in improving sensitivity in differentiating between benign and malignant lung pathology for clinical feasibility.

43. Reconfigurable Parallel Continuum Robots for Incisionless Surgery

Patrick Anderson - ME; Art Mahoney - ME; Fabien Maldonado - VUMC; Robert Webster III - ME

We propose a new class of robotic device for minimally-invasive surgery that lies at the intersection of continuum, parallel, and reconfigurable robotics. The parallel-needle concept involves the use of multiple needle-diameter devices inserted through the skin and assembled into parallel structures inside the body. The parallel structure can be reconfigured inside the patient's body to satisfy changing task requirements such as reaching initially inaccessible locations or modifying mechanical stiffness for manipulation or palpation. Another potential advantage of the parallel-needle concept is that many small (needle-sized) entry points into the patient may be preferable in terms of both patient healing and cosmesis to the single (or multiple) larger ports needed to admit current surgical robots. We have developed and experimentally validated a mechanics-based model for parallel-needle robot forward and inverse kinematics. We have also explored how to combine sensor information with the mechanics-based model to estimate the structure's shape under applied loads. The end result is a framework for shape sensing for parallel-needle robots that will enable future research on control under applied loads, autonomous motion, and force sensing, among other beneficial robot behaviors.

44. Remodeling of an Injectable, Settable, and Cell-Degradable Composite Bone Cement with Bone-like Strength in a Rabbit Femoral Plug Defect Model

Madison A.P. McEnery, Sichang Lu, John Martin, Mukesh K. Gupta, Katarzyna J. Zienkiewicz, Daniel Shimko, Kerem N. Kalpakci, Craig L. Duvall, Scott A. Guelcher

Calcium phosphate (CaP) ceramics are highly osteoconductive, but their use in weight-bearing applications is limited by their brittleness. Blending CaPs with polymers ideally enhances their mechanical properties while maintaining good osteoconductivity. We developed an injectable polythioketal urethane (PTKUR) that selectively degrades by reactive oxygen species generated by infiltrating cells during healing. Blending PTKUR with CaP particles yields a low-porosity (<5%) cement with mechanical properties exceeding trabecular bone. PTKUR/CaP composites were fabricated with tack-free times <10 min, and the low viscosity allowed for injection and in situ setting. SEM images indicated <10% porosity. Compression testing verified that both composites have compressive strength exceeding that of trabecular bone. Degradation studies demonstrated nearly 100% degradation of PTKUR after 72 h in accelerated oxidative medium and minimal degradation in PBS. The biocompatibility and remodeling of PTKUR/CaP composite cements were investigated in vivo in a rabbit femoral condyle plug defect model to assess material resorption and integration with the host bone. µCT images of plug defects after 6 weeks showed complete fill and space maintenance of the PTKUR/MG composite group compared to the MG control. 2D µCT images revealed evidence of new bone formation near the bone/cement interface for the PTKUR/MG composite comparable to the control. Injectable, settable, and cell-degradable PTKUR/ceramic composites have initial bone-like strength, degrade by cell-mediated oxidation, and remodel in vivo.

45. RNAi Nanomedicine Selectively Inhibits Rictor/mTORC2 and Improves Therapeutic Efficacy of Lapatinib In Vivo

Thomas A. Werfel [1], DM Brantley-Sieders [3,4], MA Jackson [1], TE Kavanaugh [1], KC Kirkbride [1], M Morrison Joly [5], DJ Hicks [2], VM Sanchez [4], L Lee [1], M Miteva [1], TD Giorgio [1], RS Cook [2,4], CL Duvall [1]

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The PI3K/Akt/mTOR signaling cascade is dysregulated in over 60% of breast cancers across all three major clinical subtypes, where there is mounting evidence that mTORC2 plays a unique role in driving tumor cell survival and motility. Although mTORC1/2 dual kinase inhibitors exist, no current therapeutics selectively inhibit mTORC2 while sparing mTORC1. Here, specific mTORC2 therapy was enabled by genetic inhibition of the mTORC2-specific co-factor Rictor using potent siRNA nanopolyplexes optimized through a combinatorial approach to achieve efficient siRNA delivery to solid breast tumors. Our optimized nanomedicine containing Rictor siRNA significantly decreased mTORC2 activity and tumor growth in HER2+ breast cancers through induction of cell death. Combination therapy of Rictor siRNA with the HER2 tyrosine kinase inhibitor lapatinib resulted in greater inhibition of Akt, increased tumor cell killing, and reduced tumor growth as compared to either agent alone. These collective data demonstrate that siRNA nanomedicines can effectively modulate targets previously considered 'undruggable' and underscore the therapeutic potential of blocking mTORC2 in PI3K/Akt/mTOR dysregulated cancers.

46. Selecting electrode configurations for image-guided cochlear implant programming using template matching

Dongqing Zhang, Yiyuan Zhao, Jack H. Noble, Benoit M. Dawant, Department of Electrical Engineering and Computer Science

Cochlear implants (CIs) are used to treat patients with severe-to-profound hearing loss. In surgery, an electrode array is implanted in the cochlea. After implantation, the CI processor is programmed by an audiologist. One factor that negatively impacts outcomes and can be addressed by programming is cross-electrode neural stimulation overlap (NSO). In the recent past, we have proposed a system to assist the audiologist in programming the CI that we call Image-Guided CI Programming (IGCIP). IGCIP permits using CT images to detect NSO and recommend which subset of electrodes should be active, aka the 'electrode configuration,' to avoid NSO. In an ongoing clinical study, we have shown that IGCIP leads to significant improvement in hearing outcomes. Most of the IGCIP steps are robustly automated but electrode configuration selection still sometimes requires expert intervention. With expertise, Distance-Vs-Frequency (DVF) curves, which are a way to visualize the spatial relationship learned from CT between the electrodes and the nerves they stimulate, can be used to select the electrode configuration. In this work, we propose an automated technique for electrode configuration selection. It relies on matching new DVF curves to DVF curves for which electrode configurations are known. We compare this approach to one we have previously proposed. We show that our new method produces results that approach those obtained with our previous one while being generic and requiring fewer parameters. We postulate that because this method is exemplar-based it will improve over time as our library of DVF curves increases

Submitted Abstracts

47. Steerable Robot Assisted Micro-Manipulation in the Middle Ear: Preliminary Feasibility Evaluation

Rashid Yasin MS [1]; Brendan P. O'Connell MD [2]; Haoran Yu MS [1]; Jacob B Hunter MD [2]; George B Wanna MD [2]; Alejandro Rivas MD [2]; Nabil Simaan PhD [1]

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Hypothesis: The use of a robotic manipulator with a dexterously orientable gripper will expand the ability of middle ear surgeons to perform precise tasks and access otherwise challenging anatomic regions. Background: Middle ear surgery presents unique challenges because of the constrained operative space and limited access to certain anatomic regions. Methods: A custom designed robot with a sideways-reaching gripper was used to evaluate feasibility of manipulation tasks in different middle-ear anatomical zones. Reachable workspace within the middle ear, accuracy of free-space path following, and tool steadiness were compared between robotic telemanipulation and manual control. Preliminarily assessments of the robot's clinical utility included: 1) touching the round window niche, Eustachian tube orifice, and sinus tympani; 2) placing a stapes prosthesis; 3) removal of mockup diseased tissue in the sinus tympani. Results: The reachable workspace in the middle ear was considerably greater with the robot as compared to manual manipulation using a Rosen needle. In a simple path tracing task outside the ear, robotic telemanipulation was associated with significantly reduced error. Within the middle ear, the robot contributed to steadier movement, but longer task completion time. The gripper successfully placed a 4.5 mm piston prosthesis, accessed the round window niche, Eustachian tube orifice, and removed mockup disease from the sinus tympani. Conclusion: This study demonstrates that robotic assistance using steerable tools allows surgeons to access challenging anatomic regions of the middle ear. Coordinated and accurate manipulation is evidenced by motion analyses and completion of feasibility tasks within the middle ear.

Submitted Abstracts

48. Steering Needles in the Lung is like Backing Up A Trailer

Arthur W. Mahoney, Department of Mechanical Engineering Philip J. Swaney, Department of Mechanical Engineering Robert J. Webster III, Department of Mechanical Engineering

Lung cancer is the deadliest form of cancer, and survival depends on early-stage diagnosis and treatment. Transoral access is preferable to traditional between-the-ribs needle insertion because it is less invasive and reduces risk of lung collapse. Yet many sites in the peripheral zones of the lung or distant from the bronchi cannot currently be accessed transorally, due to the relatively large diameter and lack of sufficient steerability of current instrumentation. To remedy this, we propose a new dexterous robotic system that incorporates a biopsy needle that can be transorally deployed deep within the lung and actively steered through tissue to reach small target. This robotic concept is made possible by a recent advancement in steerable needles: the flexure-tip steerable needle.   In this work, we investigate the behavior of flexure-tip steerable needles in phantom tissue and develop a mathematical model that predicts their motion.   Our model will be useful to future motion planning algorithms that assist physicians in navigating steerable needles around sensitive areas in the lung in order to safely reach peripheral nodules.

Submitted Abstracts

49. Surgeon-mounted system for continuous video of open surgical procedures

Doug Manogue* - Department of Mechanical Engineering
Eric J Noonan* - Department of Mechanical Engineering
William J Rodriguez - Department of Electrical Engineering and Computer Science
Thomas J Withrow - Department of Mechanical Engineering
Alexander Langerman - VUMC Department of Otolaryngology
*contributed equally

Capturing operating room (OR) activity via video is vastly beneficial. Recordings can enhance training, provide useful data for patients' medical records, and form the foundation to analyze OR performance and safety. Whereas video capture during laparoscopic and other camera-mediated operative approaches is simple, capture of open surgical procedures through current mechanisms is challenging; overhead-mounted cameras are limited by frequent obstructions, and head-mounted cameras result in neck strain and unsteady footage. To address this need, we developed a prototype, lightweight shoulder-mounted video rig that has the added advantage of binocular video capture. Accelerometer data demonstrates that the shoulder provides a steadier platform for video mounting than the head. Qualitatively, the prototype is comfortable, and preliminary analysis suggests that the shoulder vantage point experiences fewer obstructions than overhead mounting. This system accommodates sterile operative garb and does not interfere with surgical tasks. While refinements are ongoing, these early results suggest that a shoulder-mounted system is ideal for open surgical video capture. Future directions will focus on operative field tracking, conversion of binocular vision to VR environments, and utilization for surgical training.

50. Through the Eustachian Tube and Beyond: A New Miniature Robotic Endoscope to See Into The Middle Ear

Loris Fichera, Dept. of Mechanical Engineering; Neal P. Dillon, Dept. of Mechanical Engineering; Dongqing Zhang, Dept. of Electrical Engineering and Computer Science; Isuru Godage, Dept. of Mechanical Engineering; Michael A. Siebold, Dept. of Electrical Engineering and Computer Science; Bryan I. Hartley, Dept. of Radiology; Jack H. Noble, Dept. of Electrical Engineering and Computer Science; Paul T. Russell III, Department of Otolaryngology; Robert F. Labadie, Department of Otolaryngology; Robert J. Webster III, Dept. of Mechanical Engineering

We present a novel miniature robotic endoscope that is small enough to pass through the eustachian tube and provide visualization of the middle ear (ME). The device features a miniature bending tip previously conceived of as a small-scale robotic wrist that has been adapted to carry and aim a small chip-tip camera and fiber optic light sources. The motivation for trans-eustachian tube ME inspection is to provide a natural-orifice-based route to the ME that does not require cutting or lifting the eardrum, as is currently required. In our study, we first performed an analysis of the ME anatomy and used a computational design optimization platform to derive the dimensional and kinematic requirements for endoscopic inspection of the ME through the eustachian tube. Based on these requirements, we fabricated the proposed device and used it to demonstrate the feasibility of ME inspection in an anthropomorphic model, i.e. a 3D-printed ME phantom generated from patient image data. We show that our prototype provides 83.74% visibility coverage of the sinus tympani, a region of the ME crucial for diagnosis, compared to an average of only 6.9% using a straight, non-articulated endoscope through the Eustachian Tube.

Submitted Abstracts

51. Treating Epilepsy via Thermal Ablation: Initial Experiments with an MRI-Guided Concentric Tube Robot

Yue Chen [1,2]; Megan E. Poorman [2,3]; David B. Comber [1,2]; E. Bryn Pitt [1,2]; Cindy Liu [1,2]; Isuru S. Godage [1,2]; Hong Yu [4]; William A. Grissom [2,3]; Eric J. Barth [1,2]; Robert J. Webster, III [1,2,4]

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Epilepsy is a prevalent neurological disorder, affecting 65 million people globally. Surgical resection of the seizure focus is a potentially curative treatment for patients with seizures that electrophysiologically correlate to a focal lesion. For these patients, focal surgical resection can result in 60-70% seizure-freedom rates. However, open resection carries the risk of cognitive impairment or focal neurologic deficit. Recent innovations in MRI enable high resolution soft tissue visualization, and real-time temperature monitoring, making MR-guided ablation therapy a promising minimally invasive technique to restrict the tissue destruction to just the seizure focus. Commercial products have recently been introduced for MR-guided laser-based thermal ablation. These products require the physician drill a hole into the skull for ablation probe placement, and may not always be able to ablate the entire seizure focus when the structure has a curved shape (such as the hippocampus). Incomplete ablation of the seizure focus would lead to seizure recurrence. We have recently proposed concentric-tube steerable needles as a means to address these challenges. They enable nonlinear trajectories and offer the potential to enter the brain through the patient's cheek via a natural opening in the skull base (i.e. the foramen ovale). This poster presents our first experiments on delivering thermal ablation using our helical steerable needle system and imaging the resulting ablation zone using the MRI scanner. Experimental results show that the ablation volume can be predicted based on needle geometry. Future work will focus on MR-guided robotic ablation of specific target zones in ex-vivo animal tissues.

52. Using an Android Application to Assess Registration Strategies in Open Hepatic Procedures: A Planning and Simulation Tool

Derek J. Doss [1], Jon Heiselman [1], Jarrod A. Collins [1], Jared A. Weis [1], Logan W. Clements [1], and Michael I. Miga [1,2,3,4]

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Surface digitization with an optically tracked stylus for use in an organ-based image-to-physical registration is an approved approach for open image guided liver surgery procedures. Variability in swab data during open hepatic procedures can introduce error in alignment. While patterns of appropriate swabbing have been established in neurosurgical procedures, the application to soft tissue surgery, such as hepatic procedures, is more complex with no obvious marking procedure. Furthermore, unlike facial features that reside on a rigid cranium, there is considerable deformation during point capture due to the inherent soft-tissue contact as well as tendencies to lose contact given the swabbing coverage needed. These factors could potentially have a confounding effect on registration. As opposed to neurosurgical procedures with nearly four decades of registration experience, soft-tissue image guided liver surgery is in its infancy. As a result, we have developed an application to allow surgeons to study the performance of surface digitization patterns on registration. In addition, given the intrinsic nature of soft-tissue, we also incorporate the realism of deformation when assessing fidelity. This also has impact on training technicians who are often tasked with demarking preoperative salient features in the case of image guided liver surgery. In this preliminary investigation, we report on the construction of our application and preliminary results. The preliminary data using a mock liver phantom registration shows that different swabbing techniques do cause surface error to be distributed differently across the mock liver. Target error between registered intraoperative and preoperative targets will be assessed in the new work to be presented.

Submitted Abstracts

53. Validation of Model-Based Brain Shift Correction in Neurosurgery via Intraoperative Magnetic Resonance Imaging

Ma Luo [1], Sarah F. Frisken [2], Jared A. Weis [1], Logan W. Clements [1], Prashin Unadkat [2], Reid C. Thompson [3], Alexandra J. Golby [2], Michael I. Miga [1,3,4]

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Soft tissue deformation during neurosurgery, or brain shift, can compromise the spatial validity of preoperative imaging data. In minimizing the impact of brain shift on clinical outcome, intraoperative magnetic resonance (iMR) has shown to be a valuable tool. While iMR is the clinical gold standard in monitoring brain shift, it is not widely adopted due to cost considerations for medical centers. Therefore, a model-based and cost-effective brain shift compensation strategy could provide an additional avenue to enhance surgical care in standard procedures, while intensive cases may be referred to iMR centers. Briefly, our deformation correction pipeline uses preoperative information, namely MR image and surgical plan, to generate a deformation atlas via a biphasic biomechanical model. The atlas contains hundreds of potential deformation solutions, accounting for effects of head orientation, cerebrospinal fluid drainage, mannitol, and swelling. The optimal solution is then drawn from the atlas via an inverse approach to best fit measured surface deformation. Subsequently, preoperative image is updated accordingly to present a more accurate intraoperative anatomy. This project aims to validate our methodology with iMR. Preoperative and intraoperative MR images of 2 patients were acquired. The surface deformation is measured by selecting homologous surface points on preoperative and intraoperative images, which is utilized to drive the correction algorithm to update the preoperative image. For validation, homologous subsurface targets were determined and compared among preoperative, intraoperative and updated preoperative images. When considering moderate-to-high levels of subsurface shift (>3 mm), the developed model-based strategy demonstrates an average shift correction of 52%.

Submitted Abstracts

54. Validation of DTI-based parcellation of the thalamus in the squirrel monkey

Yurui Gao [1,2], Kurt Schilling [1,2], Iwona Stepniewska [3], Landman Bennett [2,4], Adam Anderson [1,2]

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Diffusion tensor imaging (DTI) has been used to noninvasively resolve major thalamic nuclei using an unsupervised clustering algorithm1. However, rigorous validation of the DTI-based parcellation in the thalamus has not been studied. Here, we evaluate the method by comparing the parcellation results with histology in the same non-human primate.

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Every effort was made to ensure all registrations, laboratory descriptions and abstracts were captured in this program. Please forgive any accidental omissions.

Registrants

Colette Abah
Patrick Anderson
Adam Anderson
Christopher Austin
Richard Baird
Sean Bedingfield
Cam Bermudez
Matthew Bersi
Nathaniel Bloodworth
Timothy Boire
Ivan Bozic
Amanda Buck
Brett Byram
Ahmet Cakir
Zhipeng Cao
Srijata Chakravorti
Vandiver Chaplin
Yue Chen
Logan Clements
Katherine Cochran
Jarrod Collins
Lu Davie
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Brian Evans
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Jack Noble
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Prasanna Parvathaneni
Megan Poorman
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Andria Remirez
Bryson Reynolds
Katherine Riojas
Bill Rodriguez
Margaret Rox
Nima Sarli
Melanie Schuele
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Michael Siebold
Liz Sillay
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Byron Smith
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David Vulcano
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Robert Webster III
Jared Weis
Patrick Wellborn
Thomas Werfel
Raul Wirz-Gonzalez
Tom Withrow
Xiaochen Yang
Rashid Yasin
Dongqing Zhang
Yiyuan Zhao

VISE VANDERBILT INSTITUTE IN SURGERY AND ENGINEERING

Vanderbilt Initiative in Surgery and Engineering (VISE) is a trans-institutional center that promotes the creation, development, implementation, clinical evaluation and commercialization of methods, devices, algorithms, and systems designed to facilitate interventional processes and their outcome. It facilitates the exchange of ideas between physicians, engineers, and computer scientists. It promotes the training of the next generation of researchers and clinicians capable of working symbiotically on new solutions to complex interventional problems, ultimately resulting in improved patient care.

Initiatives supported by VISE include financial support for interdisciplinary seed projects, financial support and technical assistance with the rapid-prototyping of small devices and the organization of a seminar series held bi-weekly. This Symposium in Surgery and Engineering is the culmination of the fall seminar series and it is an opportunity for VISE members to show and discuss the various collaborative projects in which they are involved. We hope this event will be the catalyst for new collaborative efforts.

Notes

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