Rochester Center for Biomedical Ultrasound

2004 Annual Report

Rochester Center for Biomedical Ultrasound

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About the Cover

The cover image of the University of Rochester Interfaith Chapel, overlooking the Genesee River, was captured one winter morning by John Young, a senior laboratory engineer in the Departments of Biochemistry and Biophysics and Biomedical Engineering at the University.

Massive Change Image Gallery

The image to the right comes from the Massive Change Exhibition and Tour, a project by Bruce Mau Design and the Institute without Boundaries, commissioned and organized by the Vancouver Art Gallery. The exhibition's key themes focus upon the emergence of design as one of the world's most powerful forces.

The RCBU submitted numerous ultrasound images created by Brian Porter for the exhibit's Image Gallery. This gallery showcases photographs made with radio waves to cosmic rays and everything in between, with the idea that new technologies are quickly making visible the as yet invisible. The exhibit is currently on tour throughout Canada, the US, and Europe. For more information and a schedule, visit: www.massivechange.com

Massive Change Image Gallery. Image courtesy of Greg Van Alstyne, IwB Director

From the Directors

From Director Kevin J. Parker

The Rochester Center for Biomedical Ultrasound (RCBU) was pleased to co-sponsor the Third International Conference on Ultrasonic Measurement and Imaging of Tissue Elasticity, held in Cumbria, United Kingdom. Gathering investigators from around the world, this event was organized jointly with Dr. Jonathan Ophir of the Ultrasonic Laboratory at the University of Texas Medical School at Houston, with Professor Jeff Bamber of The Institute of Cancer Research, Sutton, Surrey, UK, as the local host and organizer. Details of the conference start on page 23.

Elastography imaging is emerging as a promising and exciting new field with numerous approaches and clinical applications. Plans are underway for the Fourth International Conference, which is being held in Texas in October. More details about the upcoming conference can be found at the RCBU Web site:

www.ece.rochester.edu/users/rcbu/conference

The RCBU has, over the years, been a generating source of fundamental concepts and innovations. Many of today's developments—contrast agents and nonlinear techniques—have a scientific history that includes benchmark experiments at the University of Rochester.

This year's annual report documents continued progress across broads fronts, from the fundamentals of tissue ultrasound interactions to advances in three-dimensional imaging.

We welcome your comments on any of the enclosed reports.

From Associate Director Deborah J. Rubens and Chief Sonographer Nancy Carson

In 2004, the Department of Radiology Ultrasound continued to grow, increasing exam volume by six percent. Early in 2004, the sonographers began to use their new Acuson Sequoias and their new GE Logiq9. The machines represent state-of-the-art ultrasound technology, including compound imaging, speckle reduction, and voice recognition on the Logiq9, and cadence, spatial compounding, and tissue equalization on the Sequoias.

Partnering with GE, the department acquired an additional Logiq9 this fall to evaluate the latest software release. The software improves existing features such as compounding, speckle reduction, and image auto optimization. More importantly, it introduces a new approach to volume imaging using 3D transducers, including new real-time multiplaner transducers, termed "4D." This technology offers the radiologist an opportunity to manipulate data from a single scan sweep and view the anatomy or pathology from any desired plane, an option not widely applied in radiology. These new applications allow radiologists to view reconstructed ultrasound volumes the same way they view reconstructed CT and MRI data. Information from this reconstructed plane has already been shown to be diagnostically advantageous in breast, gyn, and vascular imaging.

Starting early in 2005, the department will be one of several test sites across the nation to evaluate GE's cine-loop protocols. The improved cine-loop capabilities let the sonographer acquire data in one or two volumetric sweeps, rather than multiple still images, thus improving efficiency by decreasing scan time, while actually capturing more diagnostic information.

Clinical research continues with our medical center partners from pediatric nephrology and pediatric hematology. Nephrology is studying the intimal thickness of the carotid artery as it relates to hypertension in a select group of patients. Hematology is evaluating aspirin prophylaxis in sickle cell disease. Ultrasound is used to monitor flow velocities in the circle of Willis on serial transcranial Doppler ultrasound studies.

About the Center

The Rochester Center for Biomedical Ultrasound at the University of Rochester was created in 1986 to unite professionals from the medical, engineering, and applied science communities.

The Center started with about 30 members and now has around 100 members, with several visiting scientists from locations around the world.

The Center provides a unique environment where professionals can join together to investigate the use of very high frequency sound waves in medical diagnosis along with other ultrasound-related endeavors.

The inside back page of this report shows the diverse departments involved in collaborative ultrasound research.

The Center's objectives include:

Research
Includes interaction with joint laboratories, technical discussion in formal meetings, and communication through a Center newsletter. In addition, interactions with industry, government, and foundations provide an assessment of the needs of the field and encourage mutually beneficial research programs and fellowships.

Education
Includes graduate-level courses in biomedical ultrasound and closely related fields, specialized short courses open to the international community, and post-doctorate collaborations with bioimaging areas within the University.

Innovation
The University of Rochester has a long history of leadership and innovation in biomedical ultrasound. For more than two decades, there has been steady progress in the quality of images of organs within the body which are reconstructed from the echoes of very short pulses of ultrasound.

In the late 1960s, Center member Raymond Gramiak led a team that first reported the use of an ultrasound contrast agent. At that time, agitated liquids were injected via a catheter while performing an ultrasound examination of the heart and great vessels. A dramatic increase in echoes was produced from the highly reflective air bubbles contained within the injected solution. Work has progressed through the years in this and other areas. Current projects include: nonlinear acoustics, contrast agents, 3D and 4D sonoelastography, ultrasound and MRI fusion, scattering, bioeffects, therapeutics, advanced imaging systems, and more.

The University of Rochester Medical Center

Selected Publications

SC Campbell, **JA Cullinan**, **DJ Rubens**. "Slow Flow or No Flow? Color and Power Doppler US Pitfalls in the Abdomen and Pelvis." *Radiographics*, 24(2), 497-506, 2004.

D Dalecki. "Mechanical Bioeffects of Ultrasound." *Annual Reviews of Biomedical Engineering*, 6:229-248, 2004.

OD Altland, **D Dalecki**, VN Suchkova, CW Francis. "Low-intensity ultrasound increases endothelial cell nitric oxide synthase activity and nitric oxide synthesis." *J Thrombosis and Haemostasis*, 2:637-643, 2004.

N Akashi, J Kushibiki, and **F Dunn**. "Frequency dependence of acoustic properties of aqueous glucose solutions in the VHF/UHF range." *J Acous Soc Am*, 116(1), 539-544, 2004.

MW Miller, RK Miller, LF Battaglia, WC Dewey, MJ Edwards, **WL Nyborg**, C Cox, JS Abramowicz. "The ΔT thermal dose concept 1: in vivo teratogenesis." *J Thermal Biology*, 29, 141-149, 2004.

S Mazza, LF Battaglia, **MW Miller**, WC Dewey, MJ Edwards, JS Abramowicz. "The ΔT thermal dose concept 2: in vitro cellular effects." *J Thermal Biology*, 29, 151-156, 2004.

MW Miller. "Cell size relations for sonolysis." *Ultrasound in Medicine and Biology*, 30(10) 1263-1267, 2004.

VS Dogra, **DJ Rubens**, RH Gottlieb, S Bhatt. "Torsion and beyond: new twists in spectral Doppler evaluation of the scrotum." *J Ultrasound Med*, Aug 23(8), 1077-1085, 2004.

F Lei, WS Ng, H Liu, W O'Dell, **DJ Rubens**, **Y Yu**. "Bouquet brachytherapy: the feasibility and optimization of conically spaced implants." *Radiother Oncol*, 71 S85-6, 2004. (abstract)

DJ Rubens. "Hepatobiliary imaging and its pitfalls." *Radiol Clin North Am*., March, 42(2): 257-278, 2004

LS Taylor, **BC Porter**, G Nadasdy, **PA di Sant'Agnese**, D Pasternack, **Z Wu**, **RB Baggs**, **DJ Rubens**, **KJ Parker**. "Three-dimensional registration of prostate images from histology and ultrasound." *Ultrasound in Medicine and Biology*, 30(2), 161-168, 2004.

T Varslot, B Angelsen, **RC Waag**. "Spectral estimation for characterization of acoustic aberration." *J Acoust Soc Am*, 116(1), 97-108, 2004.

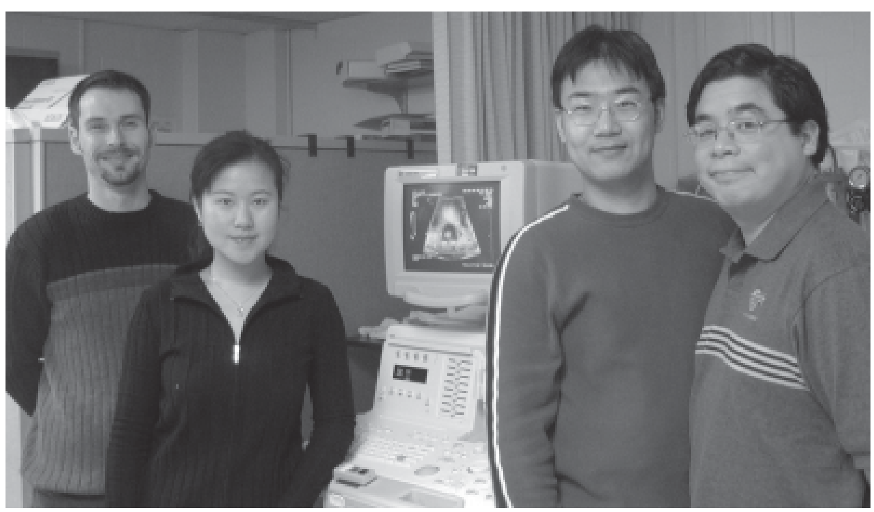
CM Spillmann, E Lomakina, **RE Waugh**. "Neutrophil adhesive contact dependence on impingement force." *Biophys J*, 87(6): 4237-45, Dec 2004.

EB Lomakina, CM Spillmann, MR King, **RE Waugh**. "Rheological analysis and measurement of neutrophil indentation." *Biophys J*, 87(6): 4246-58, December 2004.

EB Lomakina, **RE Waugh**. "Micromechanical tests of adhesion dynamics between neutrophils and immobilized ICAM-1." *Biophys J*, 86(2): 1223-33, February 2004.

Z Wu, **LS Taylor**, **DJ Rubens**, **KJ Parker**. "Sonoelastographic imaging of interference patterns for estimation of the shear velocity of homogeneous biomaterials." *Physics in Medicine and Biology*, 49, 911-922, 2004.

N Yokoyama, **KQ Schwarz**, **SD Steinmetz**, X Li, **X Chen**. "Prognostic value of contrast stress echocardiography in patients with image quality too limited for traditional noncontrast harmonic echocardiography." *J Am Soc Echocardiogr*, Jan 17(1), 15-20, 2004.



PhD students Brian Porter, Maggie Zhang, Clark Wu, and Benjamin Castaneda at the Medical Center with the GE Logiq9.

Selected Presentations

D Dalecki, SZ Child, CH Raeman. "Effect of exposure duration on lung hemorrhage from low frequency underwater sound." 148th Meeting of the Acoustical Society of America, San Diego, CA, November 2004. *J. Acoust. Soc. Am.* 116:2560, 2004.

D Dalecki, SZ Child, A Brod, **CH Raeman**. "Intestinal damage from exposure to low frequency ultrasound." 48th Annual Convention of the American Institute of Ultrasound in Medicine, Phoenix, AZ, June 2004. *J. Ultrasound Med.* 23:S18, 2004.

SM Gracewski, H Miao, **D Dalecki**, **M Miller**. "Simulation of an acoustically excited bubble near simulated cells." 147th Meeting of the Acoustical Society of America, New York, NY, May 2004. *J. Acoust. Soc. Am*. 115:2561, 2004.

M Helguera. "Test target design, fabrication, and analysis for C-scan ultrasonic system characterization." 4th International Conference on Ultrasonic Biomedical Microscanning, September 2004.

S. Levinson, Z Wu, KJ Parker. "A Comparison of methods of sonoelastography in muscle." Third International Conference on the Ultrasonic Measurement and Imaging of Tissue Elasticity, Cumbria, UK, October 2004.

C Rota, CH Raeman, D Dalecki. "Correlation of ultrasound-induced premature beats and cavitation in vivo." 148th Meeting of the Acoustical Society of America, San Diego, CA, November 2004. *J. Acoust. Soc. Am.* 116:2508, 2004.

C Rota, CH Raeman, D Dalecki. "Cardiac stimulation by ultrasound and contrast agents: the role of bubble dissolution, destruction and biological damage." 48th Annual Convention of AIUM, Phoenix, AZ, June 2004. *J. Ultrasound Med.* 23:S59, 2004.

C Rota, CH Raeman, D Dalecki. "The influence of ultrasound contrast agent dose on the production of cardiac arrhythmias and biological damage." 48th Annual Convention of AIUM, Phoenix, AZ, June 2004. *J. Ultrasound Med.* 23:S36, 2004.

DJ Rubens. "Interventional ultrasound head to toe." Singapore Cancer Center, May 2004.

DJ Rubens. "Ultrasound of acute abdominal pain." Tyco Health Care, Japan, May 2004.

DJ Rubens. "Venous doppler of the extremities." 48th Annual Convention of AIUM, Phoenix, AZ, June 2004.

DJ Rubens. "Pitfalls in the ultrasound evaluation of DVT." Poster, 48th Annual Convention of AIUM, Phoenix, AZ, June 2004.

DJ Rubens. "Pseudoaneurysms and the role of minimally invasive techniques in their management," "Practical tips for distinquishing normal from abnormal bowel on CT," and "US evaluation of testicular and penile trauma." RSNA November 2004.

KJ Parker, M Zhang. "Color in medical imaging." IS&T/SID 12th Color Imaging Conference, Scottsdale, AZ, November 2004.

LS Taylor, KJ Parker, B Porter, Z Wu, G Nadasdy, **PA di Sant'Agnese**, D Pasternack, **R Baggs**, and **DJ Rubens**. "Detection of cancer in radical prostatectomy specimens using sonoelastography." 48th Annual Convention of AIUM, Phoenix, AZ, June 2004.

S Voci, "Ultrasound pitfalls for DVT." Poster, AIUM May 2004.

Z Wu, DJ Rubens, KJ Parker. "Sonoelastographic imaging of interference patterns for estimation of the shear velocity distribution in inhomogeneous biomaterials." 29th International Symposium on Ultrasonic Imaging and Tissue Characterization, Arlington, VA, May, 2004.

Z Wu, KJ Parker. "Visualization of shear wave propagation in biomaterials with sonoelastography." Third International Conference on the Ultrasonic Measurement and Imaging of Tissue Elasticity, Cumbria, UK, October 2004.

M Zhang, LS Taylor, DJ Rubens, KJ Parker. "Three-dimensional sonoelastography imaging of HIFU-induced lesions in bovine livers: A preliminary study in vitro." 29th International Symposium on Ultrasonic Imaging and Tissue Characterization, Arlington, VA, May, 2004.

M Zhang, LS Taylor, DJ Rubens, KJ Parker. "In vitro imaging of HIFU-induced lesions in bovine livers using three-dimensional sonoelastography." Third International Conference on the Ultrasonic Measurement and Imaging of Tissue Elasticity, Cumbria, UK, October 2004.

People, Promotions, and Awards

At the November 2004 Meeting of the Acoustical Society of America in San Diego, the ASA Student Council made **David Blackstock** the first recipient of its Student Mentoring Award.

David Blackstock and **Edwin Carstensen** participated in two Pilot Project Grant (PPG) meetings on lithotripsy, held by the Indiana University Medical School in Indianapolis. They are external advisors to the grant, which is a consortium led by Indiana University, with Boston University, California Institute of Technology, and the University of Washington also participating.

Brian Porter successfully defended his PhD thesis "Three-Dimensional Medical Ultrasound Acquisition and Data Registration and Fusion" on December 10, 2004.

Brian Porter

Benjamin Castaneda is a new PhD student in Electrical and Computer Engineering at the University of Rochester. Benjamin's research will focus on image registration of B-mode ultrasound images, sonoelastography, and 3-D images reconstructed from histology slides applied to prostate specimens.

An article by Edler and Lindstrom in *Ultrasound in medicine and biology* recognized the contributions of the late **Raymond Gramiak** to the field of echocardiography. Dr. Gramiak was co-founder of the RCBU, retiring in 1988 as emeritus Professor of Radiology at the University of Rochester. The authors said he was "one of the major contributors to the development of echocardiography." The article, titled "The history of echocardiography," appeared in Volume 30, Issue 12, December 2004, pages 1565-1644.

Maria Helguera, PhD, Assistant Professor at RIT, is a co-PI in an NSF-funded grant to develop a textbook and a lab suite. The title of the book will be "Imaging in the Physical Sciences."

Helguera is also the academic coordinator of the online MS program in Imaging Science.

Morton Miller was appointed as a National Council on Radiation Protection and Measurements staff consultant to its Scientific Committee 1-4, to assist in the finalization of the NCRP report "Extrapolation of Risks from Nonhuman Experimental Systems to Humans" and to its newly formed Scientific Committee 2-1 concerning "Radiation Protection Recommendations for First Responders."

Deborah Rubens, **John Strang**, and **Susan Voci** presented a RSNA refresher course in November 2004, "Venous Doppler Sonography: Visceral and Extremity Applications." Dr. Rubens also presented "Doppler Evaluation" and "Acute Sonography of the Painful Scrotum: An Update with Special Emphasis on Doppler Diagnosis."

At AIUM October 2004, **Deborah Rubens** was the Regional Course Director for "Vascular Ultrasound."

John Strang will be the co-director of the University of Rochester PET/CT center due to open in 2005.

Susan L. Voci was promoted to Associate Professor of Radiology. She is also a participating member on ACR's Standards and Guidelines Committee.

At the AIUM Annual Convention in Phoenix, AZ, **Zhe (Clark) Wu**, PhD candidate in Electrical and Computer Engineering, won the 2004 New Investigator Award. He won for his abstract, "Sonoelastographic Imaging of Interface Patterns for Estimation of the Shear Velocity in Homogenous Biomaterials."

Clark Wu receiving his award at the AIUM Annual Convention.

Center Profile: Stephen McAleavey, PhD

Stephen McAleavey recently joined the University of Rochester Department of Biomedical Engineering as an Assistant Professor. Steve is a BS, MS, and PhD graduate of the Department of Electrical and Computer Engineering at the University.

Kevin Parker served as his advisor for his PhD thesis, "Butterfly Search Velocity Estimation: Analysis and VLSI Implementation Issues." This work provided an understanding of the performance of an ultrasound blood velocity estimator in the presence of non-uniform flow velocities from a random process perspective. Expressions predicting the estimator performance based on the random process model agreed with in vitro experiments. He proposed and evaluated methods for overcoming artifacts introduced by non-uniform flow. He made in vivo measurements of flow using this estimator with RF echo data collected from a GE Logiq 700 scanner. Finally, He described and contrasted two alternative realizations of the estimator in silicon.

Since arriving, Steve has been assembling lab facilities for biomedical ultrasound research. The centerpiece of the lab is a Siemens Antares ultrasound scanner. This state-of-the-art clinical instrument provides RF data acquisition capability that is key to the development of new imaging techniques. Other facilities include a 60 MHz bandwidth pulser/receiver, digitizing oscilloscope, micron-precision 3-axis stage, and a 75 W RF amplifier.

Novel diagnostic ultrasound imaging methods are the subject of Steve's laboratory research. The lab's goal is to develop clinically relevant techniques to satisfy currently unmet imaging needs. **Acoustic Radiation Force Impulse (ARFI) Imaging** is his principle research topic. This technique uses intense, focused ultrasound beams to displace tissue distal to the transducer. The induced displacements are on the order of 1-10 microns, large enough to track with ultrasound. The amount of displacement is related to the tissue stiffness; the stiffer the tissue is, the less it moves. This method shows great promise in differentiating tissues whose ultrasound contrast is poor but whose elastic (stiffness) contrast is marked.

Steve McAleavey in his lab with the Siemens Antares ultrasound scanner.

Also in development is a method for improved imaging of **brachytherapy** seeds—rice-grain sized radioactive pellets used in prostate cancer treatment. To place the seeds accurately, the physician often uses ultrasound imaging as a guide. However, the seeds can be difficult to see once they leave the needle. Steve's idea is to vibrate the seeds with an alternating magnetic field, and detect the micron-level vibrations with Doppler ultrasound. Preliminary phantom work on this method has been very promising. While at Duke University, Steve was awarded a grant by the US Army to investigate this method.

Steve is teaching two classes, Signals and Measurements in Biomedical Engineering, an undergraduate course, and Advanced Biomedical Ultrasound, a graduate course. The Signals course is an investigation of instrumentation and signal processing techniques involved in biomedical data acquisition.The graduate course covers the theoretical basis of ultrasound imaging formation and provides a close study of the practical implementation of ultrasound imaging in modern clinical scanners. Topics include linear acoustic systems, spatial impulse responses, the k-space formulation, methods of acoustic field calculation, dynamic focusing and apodization, scattering, the statistics of acoustic speckle, speckle correlation, compounding techniques, phase aberration correction, velocity estimation, and flow imaging.

When asked what made him decide to return to the University, Steve said, "Rochester is one of a handful of universities in the country with both a strong ultrasound research program and an associated hospital nearby. The combination of outstanding faculty and students, a long history of ultrasound research, and an excellent teaching hospital made Rochester a compelling choice."

Biophysical bases of pulsed ultrasound bioeffects

Morton W. Miller, P.I.
NIH sponsorship (R37EB00213-29)

Dr. Miller's NIH-sponsored research project focuses on mechanical and thermal aspects of ultrasound-induced bioeffects. For the former, general support was obtained for the hypothesis that cell size is an important physical factor in ultrasound-induced hemolysis. Erythrocytes from a range of mammalian species were used. Each species has its own characteristic erythrocytic volume, thus facilitating a test of the hypothesis. Under a number of different experimental ultrasound exposure conditions and cell densities it was discerned that cell volume (i.e., size) is an apparently critical factor in US-induced hemolysis.

Dr. Miller also provided encouragement and partial financial support for Professor Sheryl Gracewski's recent JASA-submitted paper: "Ultrasonic excitation of a bubble near a rigid or deformable sphere: Implications for ultrasonically-induced hemolysis." One- and two-dimensional models were developed to investigate interactions between ultrasonically-excited bubbles and model "cells." The project's overall aim is to distinguish between symmetric and asymmetric bubble collapse in cell systems involving close proximity of bubbles and cells or surfaces. The presence of a rigid or deformable sphere had little effect on bubble expansion, but caused an asymmetric collapse and jetting for tested conditions.

A third project on "Biological and environmental factors affecting ultrasound-induced hemolysis in vitro: 5. Temperature" is nearing completion in collaboration with Dr. Charles C. Church, National Center for Physical Acoustics (NCPA). The "bioeffects" part of the project has been completed and the NCPA staff is providing calibrations of the transducers at varying temperatures. The overall results are supportive of the hypothesis that cold (i.e., ~ 0°C) erythrocytes will display substantially greater amounts of ultrasound-induced hemolysis than the physiological (37°C) erythrocytes because of a temperature-related transition in membrane fluidity leading to increased fragility.

We have made considerable progress investigating ultrasound-induced thermal effects and mechanisms of action. Two papers were published demonstrating the utility of the $\triangle T$ thermal dose concept, the first relating to in vivo effects, the second to in vitro effects. For the former, pregnant rats (day 9.5 of gestation) were exposed to heated water regimens to raise (i) the pregnant dam's core temperatures or (ii) surgically-exteriorized pregnant uteri to 5°C for an equivalent 11.3 minute exposure period (i.e., a thermal dose of t3.5 = 11.3 min). Under these conditions, the yields of anomalous fetuses were comparable, thus providing evidence that the thermal dose to the mother has little if any effect on fetal outcome.
For the latter, it was initially hypothesized that in vitro cellular functionality (e.g., fastest cell doubling time) would be maximal at each cell line's respective historical physiological temperature (HPT). Two cell lines were used, one of human origin (HPT = 37.0°C) and the other of guinea pig derivation (HPT = 39.5°C). Both grew best at their respective HPT, and both grew less well at ± 2.5°C of their respective HPT (Figure 1). The hypothesis was supported. Research is continuing in this area with a goal of determining activation energies for hyperthermia-induced birth defects. The rationale for this goal is that once the activation energy is determined it can provide strongly predictive outcomes for any combination of temperature elevation and duration of exposure.

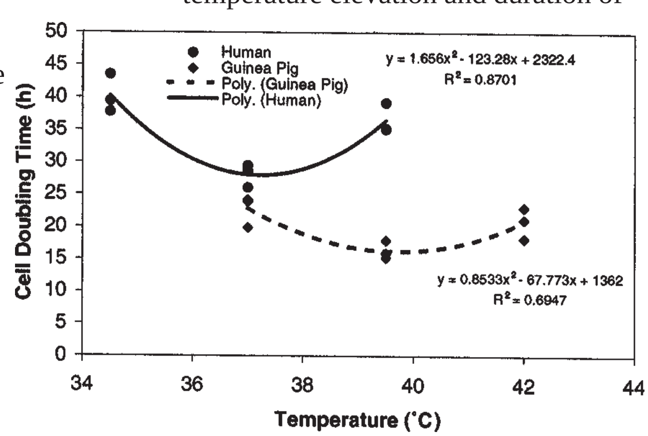


Figure 1: Cell doubling times (h) for human and guinea pig in vitro

Test target design, fabrication, and analysis for C-scan ultrasonic system characterization

Maria Helguera

The Ultrasound Imaging Lab at the Chester F. Carlson Center for Imaging Science at the Rochester Institute of Technology has been involved in the characterization of three different generations of ultrasound-based C-scanning systems. We are currently developing a set of quantitative standards for calibration.

Ultrasound is used extensively for medical imaging, nondestructive testing, and underwater acoustics. Several scanning modalities such as A-scan, B-scan, and C-scan are often used. Although appropriate test targets have been developed for B-scan imagers, very little attention has been paid to C-scanners. In order to successfully characterize these systems, a quantitative measure must be performed. The Modulation Transfer Function (MTF) is one of the most commonly used quality metrics of any linear shift invariant imaging system, though a test target must first be developed.

A direct measurement of MTF normally requires sinusoidal test patterns of various different spatial frequencies. In ultrasound, this implies that patterns should have an acoustic impedance mismatch that varies in a sinusoidal fashion. This is difficult if not impossible to achieve. An alternative method is to measure the system response to line and edge target inputs. This project describes the theory to calculate the MTF from the system response to a line or edge input. We created polyethylene terephthalate (PET) film phantoms in collaboration with the Microelectronics Department at the Rochester Institute of Technology. We laser etched a suitable pattern into the film and acquired images using the scanners.

We wrote a computer routine in IDL to extract information from the imaged resolution targets. We also used this same program to compare MTFs calculated from different test targets presented at different angles. We then compared the resolution information to MTF data calculated from a stand-alone transducer, identical to those used within the systems, imaging the edge of a glass plate immersed in oil.

Ultrasound Imaging Lab at the Rochester Institute of Technology

Maria Helguera

The research at the Ultrasound Imaging Lab at the Chester F. Carlson Center for Imaging Science has been concentrating on:

1. Development of resolution test targets for high frequency ultrasound C-scanners.
2. Non-contact ultrasound characterization of polymeric layers of powder coated plates and non-contact ultrasound characterization of paper substrates.
3. High frequency characterization of skin.

There are four students working in the lab: Raj Pai Panandiker and Niranjan Tallapally are graduate students working on their PhD, and Jeffrey Meade and Stephanie Shubert are undergraduate students. Stephanie is working on her senior project and Jeff is a third year student deeply involved in research.

Emergency Department Ultrasound

Jefferson Svengsouk, MD, RDMS, FACEP, established the emergency medicine ultrasound program at Strong Memorial Hospital in 2001.

The Emergency Department has two dedicated stand-mounted SonoSite 180 Plus ultrasound machines. One SonoSite is stationed in the trauma/critical care bay; the other is equipped with four probes and is mobile through the department.

The six major applications of emergency medicine ultrasound include: trauma (FAST), abdominal aortic aneurism, biliary, limited cardiac, renal, and first trimester pregnancy. Ultrasound guidance of invasive procedures is also used in the Emergency Department. The use of ultrasound at the bedside allows for rapid diagnosis of life threatening medical conditions, rapid disposition to definitive therapies, earlier discharge of stable patients in an era of emergency department overcrowding, and increased success with complex invasive procedures.

Dr. Svengsouk is interested in developing and expanding the use of ultrasound technology to improve the education of residents and medical students, and to enhance Emergency Department patient care.

Obstetrics and Gynecology Ultrasound Unit

Eva Pressman, MD

The OB/GYN Ultrasound Unit continued to update its equipment and offerings in 2004. The unit purchased two new GE Voluson scanners with real-time three-dimensional capability. Several staff members completed training in nuchal translucency measurement and are offering first trimester screening for aneuploidy to the Rochester community.

The unit performed more than 16,700 obstetric and gynecologic procedures. In addition to diagnostic sonograms, the unit performed 552 amniocenteses, 66 chorionic villus samplings, 396 sonohysterograms, and 5 fetal blood transfusions.

Current research projects include assessment of pulsatile fetal growth (see the abstract on this page) and region-specific humerus and femur length for prediction of trisomy 21.

Pulsatile versus continuous growth in the human fetus

A.Gordon Fry, Deborah Pittinaro, Shirley Eberly

Objective
To determine if fetal growth occurs in a pulsatile rather than continuous fashion.

Study design
Non-smoking women of normal body habitus, with medically uncomplicated, singleton pregnancies, were enrolled between 26 and 29 weeks gestation. Only data from pregnancies delivering normally grown fetuses at term, in women with normal weight gain, were included. Sonographic fetal biometric parameters were measured frequently, with a goal of three times per week, for a minimum of four weeks. For each fetus, six replicate measurements, obtained by a single examiner, were made on each of five parameters:

- Biparietal diameter (BPD)
- Head circumference
- Abdominal circumference
- Humerus length
- Femur length

For each fetus and parameter, a second degree polynomial regression on gestational age was generated. Under the assumption of pulsatile growth, a cyclical pattern of positive and negative residuals from a fitted curve would be expected. We used a runs test to examine the randomness of the regression residuals. Under the assumption of continuous growth, serial growth increments would be expected to follow a Gaussian distribution. For each fetus and parameter, we tested serial growth increments for normality using the Shapiro-Wilk test. P values $< .05$ were considered significant.

Results and conclusion
Eight subjects meeting inclusion criteria, with a mean gestational age at entry of 28.6 weeks, were examined. An average of 15 observations per subject were obtained. One-eighth BPDs demonstrated a nonrandom pattern in the residuals ($P < .05$). We did not observe patterns supporting pulsatile growth for any other parameters in any fetus studied.

These findings demonstrate minimal support for a pulsatile pattern of fetal growth. Increasing the number of observations per subject may improve the ability to detect a pulsatile pattern.

Spectral estimation for characterization of acoustic aberration

By Trond Varslot, Bjorn Angelsen, and Robert C. Waag

In this study, we found parameters in a linear filter model for ultrasonic propagation using statistical estimation. The model employs an inhomogeneous-medium Green's function that is decomposed into a homogeneous-transmission term and a path-dependent aberration term. We estimated power and cross-power spectra of random-medium scattering over the frequency band of the transmit-receive system by using closely situated scattering volumes. We obtained the frequency-domain magnitude of the aberration from a normalization of the power spectrum. The corresponding phase is reconstructed from cross-power spectra of subaperture signals at adjacent receive positions by a recursion. The subapertures constrain the receive sensitivity pattern to eliminate measurement system phase contributions. The recursion uses a Laplacian-based algorithm to obtain phase from phase differences. We acquired pulse-echo waveforms from a point reflector and a tissue-like scattering phantom through a tissue-mimicking aberration path from neighboring volumes having essentially the same aberration path. Propagation path aberration parameters calculated from the measurements of random scattering through the aberration phantom agree with corresponding parameters calculated for the same aberrator and array position by using echoes from the point reflector. The results indicate the approach describes, in addition to time shifts, waveform amplitude and shape changes produced by propagation through distributed aberration under realistic conditions.

Doppler myography: ultrasonic localization of acoustic myographic signals

Stephen F. Levinson, Hiroshi Kanai, Hideyuki Hasegawa

Introduction

Skeletal muscles generate low-frequency sounds when they contract. These sounds originate from resonant vibrations of muscle fibers and their frequency is related to fiber length and tension. Although more than two decades have passed since acoustic myography (AMG) was first described, clinical applications have been limited to neuromuscular junction monitoring during anesthesia. With few exceptions, AMG has provided little more information than surface electromyography (EMG).

Recent improvements in ultrasonic Doppler technology have made it possible to detect sub-micron displacements. Indeed, the measurement of heart sounds propagating in myocardial tissue has been reported. We hypothesize that a similar technique can be used to detect and possibly image skeletal muscle vibrations. This could lead to a biomechanical analog of needle EMG and could provide a noninvasive alternative.

Methods

As many different terms appear in the literature, we refer to them as:

- AMG—the phenomenon of muscle fiber vibration
- Phonomyography (PMG)—the recording of AMG signals at the skin surface
- Doppler myography (DMG)—the recording of AMG using Doppler ultrasound

We conducted a single subject exploration of DMG by placing an ultrasound transducer over the flexor forearm group. We obtained Doppler signals during active grasp and adjusted the range gate to be within the flexor digitorum superficialis (FDS). Surface EMG and PMG signals were simultaneously recorded. We measured the subject's grip strength using a grip dynamometer (Figure 1).

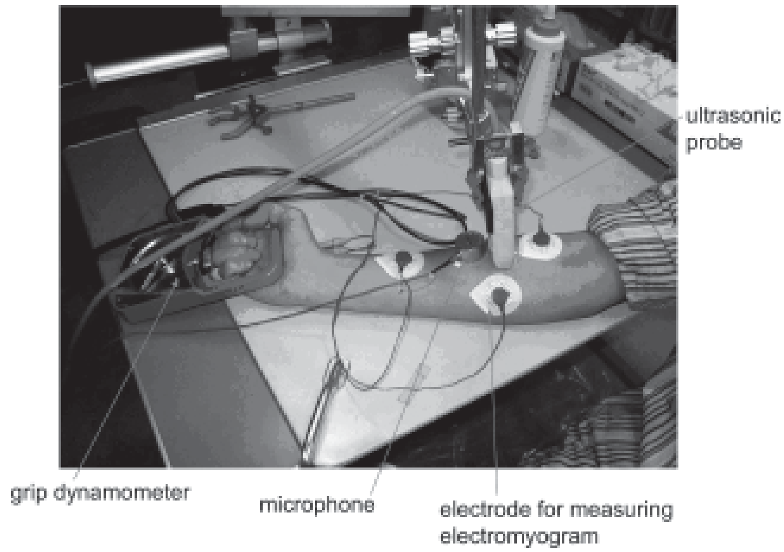


Figure 1: Apparatus for simultaneous measurement of surface electromyogram (EMG), phonomyogram (PMG) and Doppler myogram (DMG) in the forearm during grasp. Grip strength is measured using a grip dynamometer.

Results

We obtained simultaneous recordings for a variety of grip strengths. Vibrations are evident in the DMG recordings, however, we also observed translational motion (Figure 2). As with EMG, it is likely that filters need to be implemented to remove unwanted components from the DMG signal. Additional experiments are required to determine the optimum ultrasound parameters and configuration. Still, we believe that this is an important first step and that, with additional research, DMG could become a clinically useful test. The addition of real-time imaging capabilities could lead to a powerful new diagnostic tool.

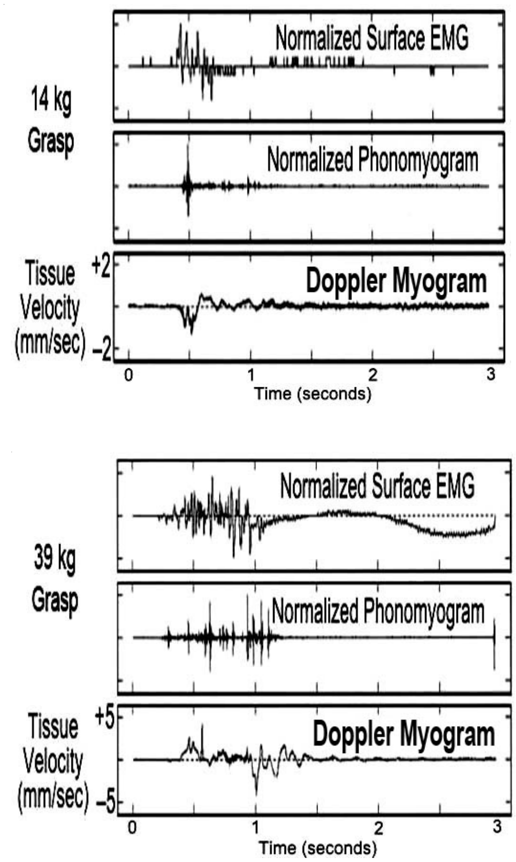


Figure 2: Simultaneous recordings of surface EMG (top), PMG (middle) and DMG (bottom) signals in the flexor digitorum superficialis during 24 kg of grasp.

Three-dimensional sonoelastography for in vitro detection of prostate cancer

Lawrence S. Taylor, Deborah J. Rubens, Brian C. Porter, Zhe Wu, Raymond B. Baggs, P. Anthony di Sant'Agnese, Gyongyi Nadasdy, David Pasternack, Edward M. Messing, Priya Nigwekar, Kevin J. Parker

Purpose

Three-dimensional sonoelastography imaging was evaluated for in vitro prostate cancer detection. The statistical outcomes from lesions within whole prostatectomy specimens are reported.

Methods

Using an Institutional Review Board-approved, HIPAA compliant protocol with informal consent, 19 prostatectomy specimens with biopsy proven prostate cancer were scanned in 3D using conventional B-scan and sonoelastography using vibrations above 100Hz. Step-sectioned whole-mount histology was utilized to create a 3D volume of the prostate and tumors within it. B-scan ultrasound images and regions of low vibration in the sonoelastography images (hard regions) were formatted in 3D.

The lesions in the nineteen cases were analyzed as two groups: G1) pathology-confirmed tumors of 1.0 cc or greater; and G2) pathology-confirmed tumor size less than 1.0 cc. G1 cases were evaluated for B-scan ultrasound and sonoelastography vs. histology as a reference standard and were scored as either a true positive, a false positive, a true negative, or a false negative. G2 cases were evaluated for sonoelastography only. True positives required 3D lesion correlation between pathology and imaging data.

Results

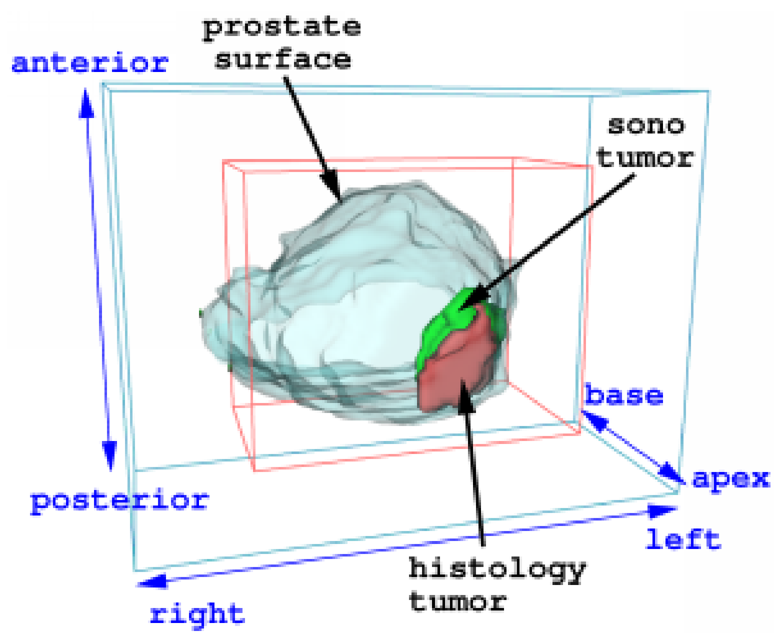
G1 (7 lesions with tumor volume 1.0 cc or greater): Sonoelastography: accuracy of 55%, sensitivity of 71%. B-scan: accuracy of 17%, sensitivity of 29%. Mean tumor size is 3.1cc +/- 2.1cc.

G2 (22 lesions with tumor volume less than 1.0 cc). Mean tumor size is 0.32 cc +/- 0.21 cc.
Sonoelastography: accuracy of 34%, sensitivity of 41%, false positives: 6.

Conclusion

Sonoelastography performed considerably better than gray-scale sonography in the detection of prostate cancer.

Sonoelastography helps improve detection of tumors over 1 cc. Future investigation may include higher vibration frequencies to improve detection of smaller tumors.



Three-dimensional reconstruction of prostate cancer within the gland surface. The prostate surface (transparent blue) was reconstructed from B-scan data; tumor data from sonoelastography and histology are indicated by arrows. Apex, base, anterior, posterior, right, and left connotations are indicated on the figure.

Three-dimensional sonoelastography imaging and viscoelastic modeling of HIFU-induced lesions in bovine livers in vitro

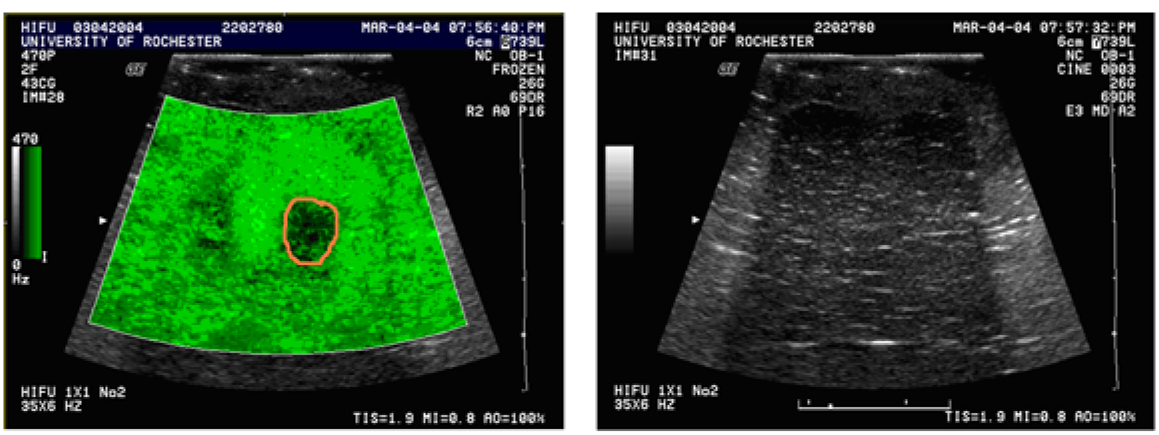
Man Zhang, Lawrence S. Taylor, Deborah J. Rubens, Kevin J. Parker

High intensity focused ultrasound (HIFU) is a promising therapeutic method that creates coagulation necrosis for non-invasively killing malignant tumors within a well-defined volume in the tissue. In this study, we investigated sonoelastography for the visualization of HIFU-induced lesions in bovine livers in vitro. Furthermore, we used mechanical testing and viscoelastic modeling to clarify the relationship of the soft tissue characteristic and the sonoelastography image formation.

We cut the cubic tissue samples (~4 x 4 x 4 cm^3) from fresh bovine liver and then degassed them overnight. We used a single-element concave HIFU transducer to create HIFU lesions in the tissue sample. We acquired a volumetric series of 2D sonoelastography images from the liver-embedded agar phantom. Each lesion is displayed as a dark area surrounded by a bright green background in the image. We used IRIS Explorer to reconstruct 3D lesion images. After, we examined imaging lesions by gross pathology to verify their shape, dimensions, and volume. To test the tissue viscoelasticity, an MTS machine carried out uniaxial unconfined compression. The Kelvin-Voigt Fractional Derivative (KVFD) model was applied as the viscoelastic model.

The gross pathology results showed that HIFU lesions were relatively uniform, palpably harder, and brighter than the normal tissue. The mean volumes of three 1 x 2 compound lesions, three 2 x 2 lesions, and three 3 x 3 lesions measured by fluid displacement were 1.8 cm^3, 2.4 cm^3 and 6.0 cm^3, respectively. As the smallest lesion in the test, a single HIFU lesion with 1.3 cm^3 in volume was also successfully detected by 3D sonoelastography. The mean sonoelastography volume of the 10 lesions was 83% of the volume measured by fluid displacement. Curve fitting results indicated that the stiffness ratio of the HIFU lesion and normal bovine liver was 8.4:1.

We found a good correlation (R2 = 0.9749) between the lesion dimensions determined by 3D sonoelastography and gross pathology. The KVFD model may successfully illuminate tissue viscoelastic effects on sonoelastography imaging. This study demonstrates that sonoelastography is a potential real-time method to accurately monitor the HIFU therapy of cancerous lesions.



A small HIFU lesion with 1.3 cm^3 in volume detected by 3D sonoelastography

Anisotropic elasticity and viscosity deduced from supersonic shear imaging in muscle

Stephen F. Levinson, Stefan Catheline, Mathias Fink

Introduction

Although the role of viscoelasticity in muscle mechanics is well recognized, methods for measurement in situ are limited. Recent advances in elastography have made possible the imaging of viscoelastic moduli within individual muscles. We have investigated a new approach, supersonic shear imaging (SSI), which combines high frame-rate (5 kHz) ultrasound with acoustic radiation force induction of shear plane waves transients. The elastic moduli can then be deduced from the propagation of these waves, and the viscous moduli from their attenuation.

Methods

We applied SSI elastography in a single subject. With the subject seated comfortably, we obtained ultrasound image sequences from the right (dominant) biceps during sustained contractions. Holding the subject's elbow at 90°, we applied various loads by having the subject hold known weights. In addition, we collected data with the forearm supported (unweighted) and unloaded (limb weight only). We acquired image sequences and calculated tissue displacements using frame-to-frame cross-correlation.

Results

We used displacement image sequences to reconstruct speed of sound maps (Figure 1) in both the transverse and axial (longitudinal fiber orientation) directions. We obtained average shear elastic moduli from these (Table 1). We could not observe propagation in the transverse direction for loads greater than 0.8 kg. It is evident that the axial elastic moduli are significantly greater than their transverse counterparts, and that both increase with load.

Although we currently lack a direct means of calculating viscosity, it is evident from the observed attenuation of the induced waves that transverse viscosity is significantly greater than axial viscosity and that transverse viscosity increases dramatically with load to the point that propagation is suppressed entirely at greater loads. Whereas the significance of these results is not clear, we anticipate that knowledge of anisotropic and dynamic viscosity could have a significant impact on biomechanics.

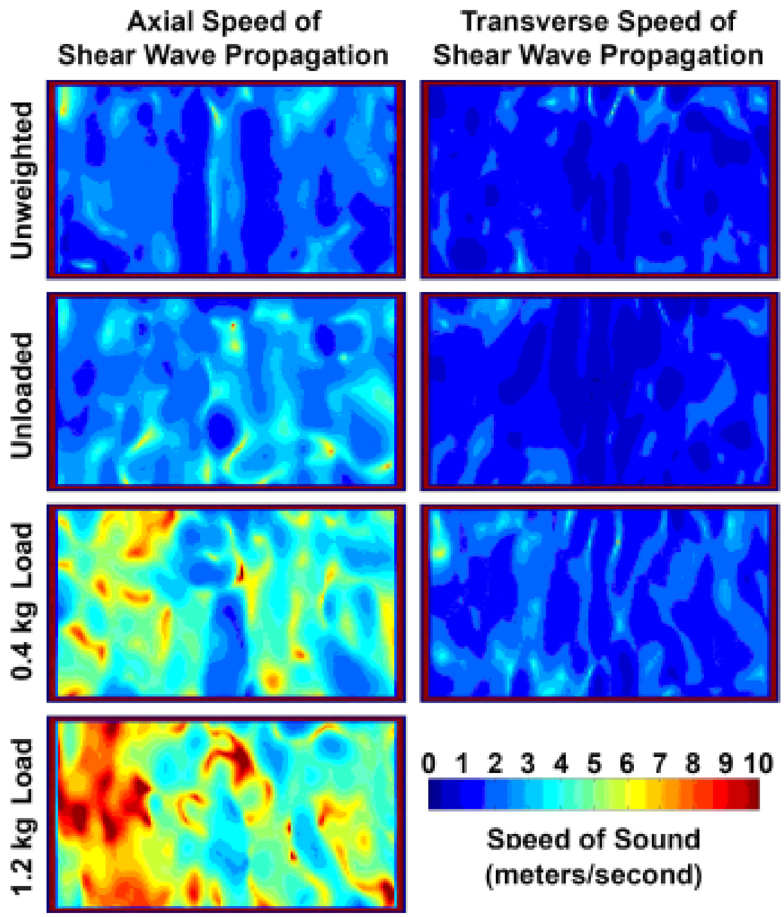


Figure 1: Speed of sound images in a for axial and transverse propagation at four applied loads. Propagation in the transverse direction did not occur above 0.8 kg.

	Unweighted	Unloaded	0.4 kg	0.8 kg	1.2 kg	1.6 kg	2.0 kg
Axial	4.0	7.3	47.2	50.8	59.7	82.5	94.6
Transverse	1.2	1.3	1.8	4.1	-	-	-

Table 1: Axial and transverse shear elastic modulus values (kPa) in the biceps brachii as a function of the applied load.

Investigations of the response of tissues to underwater sound

Yixen Ren, Sally Z. Child, Carol H. Raeman, Sheryl M. Gracewski, Edwin L. Carstensen and Diane Dalecki

Investigations are underway in our laboratory to study the effects of underwater sound on biological tissues. These projects are supported by the US Navy and have relevance to the safety of divers and marine mammals exposed to sonar fields. Frequencies of interest span the large range from ~100 Hz to ~200 kHz. These investigations aim to develop a greater understanding of the response of biological tissues to underwater sound necessary for the development of guidelines for the safe use of sonar.

Low frequency acoustic fields
Through several different avenues of investigation, we have shown that murine lung and intestine can respond to low frequency acoustic fields as resonant structures. Within our laboratory, two specialized exposure systems are available for the generation of low frequency (100-3000 Hz) underwater sound fields. Measurements of acoustic scattering near murine lung demonstrated a pronounced resonance at ~335 Hz for adult mice. Measurements of the displacement amplitudes of lung, using a pulse-echo ranging technique, were consistent with observations made from acoustic scattering measurements. Exposure to low frequency underwater sound at the resonance frequency of the lung can produce damage to the lung and surrounding tissues such as the liver. Effects on the liver are an indirect effect of the oscillation of the lung rather than a direct action of the sound. The intestine also contains gas and can respond as a resonant structure in an underwater sound field. Since the volume of a gas body in the murine intestine is less than the lung volume, the resonance frequencies of intestinal gas bodies investigated were within the frequency range of ~700-2500 Hz. Damage to the gas-filled intestine produced by exposure at the resonance frequency, however, was significantly less pronounced than that observed with the lung.

USRD type G40 calibrator used for the genertion of low frequency underwater sound fields in the 100 - 1000 Hz range.

Gas bubble studies
Recent studies in vitro measured the response of gas bubbles to low frequency sound and compared the results to analytical and finite element models (FEM). FEM is a numerical method for calculating stresses and deformations in complex geometrical structures. Balloons of different radii (0.85 cm, 1 cm and 1.25 cm) were exposed to low frequency sound swept from 100 to 500 Hz at a pressure of 1000 Pa. We determined the resonance frequency of the balloon by measuring the acoustic scattering near the balloon and/or detecting the displacement amplitude of the balloon surface using a pulse echo ranging technique. The measured resonance frequencies of the balloons were consistently lower than analytical predictions by about 12%.

To investigate the role of the exposure tank on the resonance frequency, we built a FEM model to simulate the frequency response of an air bubble under our experimental conditions. The program was written in Nastran-Patran and can perform fluid-structure analysis for direct frequency responses. The scattered field near the balloon and the displacement amplitude of the balloon surface were calculated over the frequencies of interest. Compared to the linear analytical theory, the FEM model accounts for the limited volume of water and restraint of the tank. Resonance frequencies computed with the FEM agreed remarkably well with experiments for all balloon sizes investigated.

Other projects
Work continues on several paths of investigation. Ongoing projects continue to focus on determining the mechanism of action for lung damage in response to exposure to low frequency underwater sound. Computational efforts aim to model the response of gas bodies exposed to underwater sound. Studies are also underway to characterize the response of intestine and heart to underwater sound fields when microbubbles are present in the vasculature. Additional studies are characterizing the response of tissues to underwater sound fields for frequencies ranging up to ~200 kHz.

URI/Field: A Matlab interface between the Siemens Ultrasound Research Interface and Field II

Stephen A. McAleavey and Gregg E. Trahey

A collection of software tools called URI/Field performs linear acoustic simulations matched to the Siemens Antares scanner. URI/Field simplifies simulation of a state-of-the-art commercial scanner. URI/Field is an adjunct to the Siemens Ultrasound Research Interface (URI) software option on the Siemens Antares scanner. The URI allows beam-summed RF data and associated beamforming parameters (header data) to be recorded for off-line processing. URI/Field performs matched simulations based on this header data. URI/Field is implemented entirely in Matlab and thus runs on a wide range of computer systems.

URI/Field relies on Jensen's Field II software (www.es.oersted.dtu.dk/staff/jaj/field/) to perform the acoustic simulations by the spatial-impulse response method. URI/Field provides a set of Matlab functions that automatically configure Field II to simulate apertures matched to transducer and scanner settings indicated in the URI header. Transmit and receive beams are specified, which are steered and walked across the aperture as in the physical system, as opposed to the more common practice of simulating scanning by phantom translation. Functions for scan simulation, beam intensity estimation, envelope detection, and scan conversion are included in the URI/Field package and may be called from the Matlab command line as desired.

Simulation data is divided into three logical structures. A **probe** data structure contains fixed, transducer-specific information—geometric and impulse-response data. A **beamset** data structure contains information related to beam formation parameters—beam direction, origin, apodization and focal characteristics. Both of these structures may be generated automatically from a URI data file, or may be manually created to simulate arbitrary systems. The third structure, **phantom**, contains positions and amplitudes of scatterers to be imaged. Commands for creating simple wire target and lesion phantoms are included.

A graphical user interface (GUI) facilitates common tasks. Using the GUI, URI files may be loaded and apertures created automatically. Scans are simulated and beamplots calculated with simple menu commands. Graphical probe, beamset, and phantom editors are included for the creation or modification of the related data structure. Using these editors, modifications to a baseline scanner configuration may be simulated easily, or completely user-defined systems may be simulated. The GUI allows simulations to be launched as separate processes on the local machine, or as batch jobs on a remote machine. The flexible GUI reduces common simulation tasks to simple point-and-click operations.

Powerful commands make it possible to describe an ultrasound system at a relatively high level and perform common simulation tasks easily. GUI editors simplify the inspection and modification of URI derived parameters and allow the specification of arbitrary scanners.

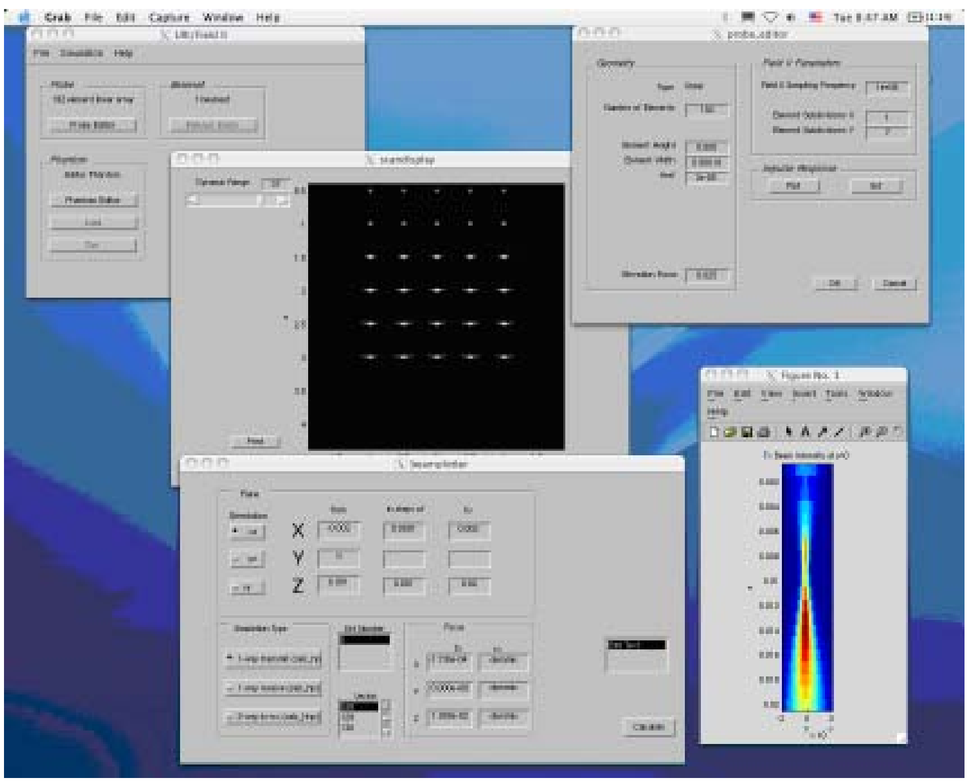


Figure 1. Screen shot of the URI/Field GUI in operation. Top left: root URI/Field window. Top right: probe editor, with controls for element number, spacing, kerf, inpulse response. Bottom: beamplotter command window, with slice and vector selection controls. Bottom right: output of the beamplotter for an apodized transmit beam. Center: simulated scan of a set of wire targets.

Cardiac stimulation by ultrasound, part I: dependence on pulse duration

Claudio Rota, Carol H. Raeman, Sally Z. Child, Diane Dalecki

In recent years, experiments in our laboratory have demonstrated that, under appropriate exposure conditions, ultrasound can produce cardiac arrhythmias. For example, the threshold for producing a premature ventricular contraction (PVC) in the murine heart with a single 5-ms pulse of 1.2 MHz ultrasound is ~ 2 MPa. The likelihood of producing a premature contraction is dependent upon (1) the acoustic properties of the ultrasound pulse (e.g. frequency, pressure amplitude, pulse duration etc.) and (2) the presence of gas nuclei in the heart. The presence of microbubble contrast agents in the vasculature significantly reduces the threshold for premature cardiac contractions.

Recent work in our lab has investigated the dependence of the threshold for ultrasound-induced PVCs on the duration of the acoustic pulse when contrast agents are present in the blood. Ultrasound exposures were performed at 200 kHz and pulse durations ranging from 40μs to 100 ms were investigated. Studies in our lab have shown that exposure of murine hearts to ultrasound at 200 kHz with 1 ms pulse durations can produce premature beats with negative pressure amplitudes as low as 1 atm (0.1 MPa). Compared to diagnostic frequencies, 200 kHz pulses are significantly more effective stimuli of PVCs. Also, gross vascular damage or compromised electrophysiology was not observed when the mouse heart was exposed at 200 kHz. Thus exposures at 200 kHz stimulated the heart while minimizing cardiac damage.

Threshold studies were performed with mice injected with a contrast agent (Optison®). A total of eight pulse durations were investigated (0.04, 0.1, 0.5, 1, 2, 5, 20 and 100 ms). Each study consisted of n = 6 mice. Each mouse received two bolus injections (3μL/bolus). The first bolus was administered prior to the first ultrasound pulse and the second bolus was administered half-way through the exposure series. Each exposure consisted of a single pulse of ultrasound at 200 kHz. Pressure amplitudes tested were 0.05, 0.1, 0.15 or 0.2 MPa.

For relatively long pulse durations (i.e., between 0.5 and 100 ms), the threshold for producing a premature contraction was independent of pulse duration. However, shorter pulse durations were significantly less likely to produce a premature beat. The 50% effectiveness levels (i.e., the pressure amplitude that produced a 50% probability of triggering a premature beat) were estimated for each pulse duration. These results are summarized in Figure 1. Also shown in this figure is a typical strength-duration curve obtained by electrical stimulation. For both ultrasound and electrical stimulation, the pulse duration dependence is essentially flat for durations above 0.5-1 ms but rises rapidly with shorter pulses. The qualitative agreement between the strength-duration curves for ultrasound and electrical stimulation provides insight on the general dependence of cardiac stimulation on pulse duration.

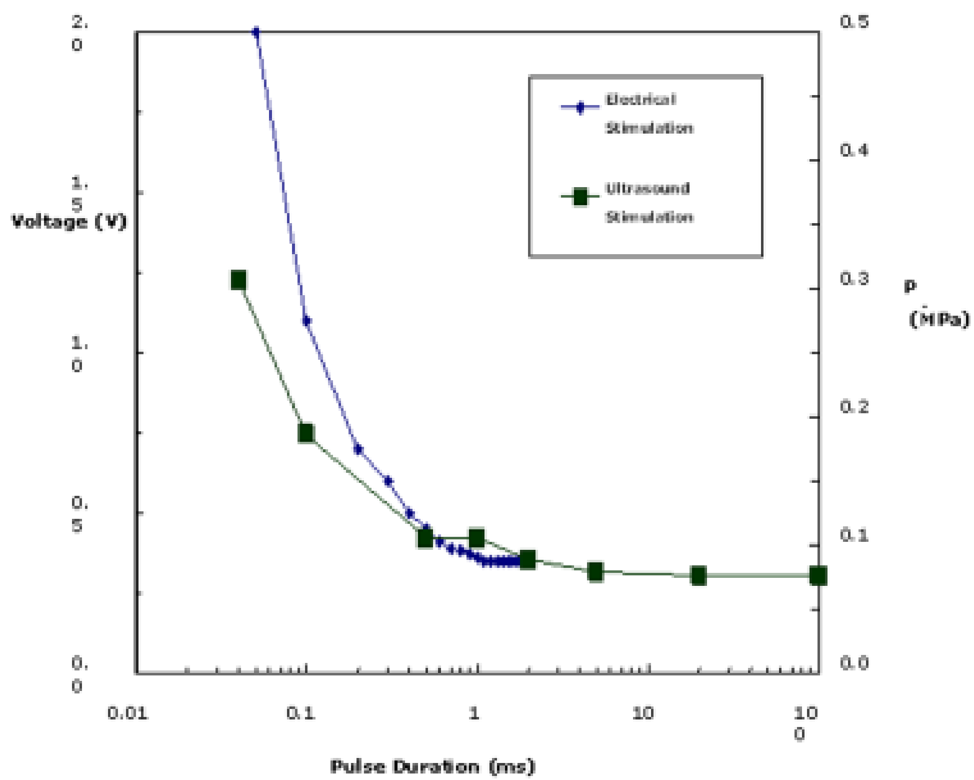


Figure 1. Strength-duration curve comparison between electrical and ultrasound stimulation. Electrical stimulation data (in V) was adapted from a study performed on a patient at the time of pacing lead implantation (Ellenbogen and Wood in Cardiac Pacing and ICDs 3rd ed., Blackwell Science, Figure 2.2; 2002). Ultrasound stimulation data (in MPa) refers to the 50% effectiveness of ultrasound.

Cardiac stimulation by ultrasound, part II: cavitation detection

Claudio Rota, Carol H. Raeman, Sally Z. Child, Diane Dalecki

Our laboratory research has actively focused on understanding the physical mechanisms responsible for ultrasound-induced arrhythmias. Results of several investigations in our lab are consistent with the hypothesis that acoustic cavitation is the mechanism for the production of premature cardiac contractions with ultrasound. Acoustic cavitation can be defined as the interaction of a sound field with a gas bubble in a liquid medium. The frequency dependence of the effect is consistent with the dependence of the threshold for inertial cavitation on frequency. Gas bubbles in vivo are relatively rare among soft tissues such as the heart. However, the presence of microbubble ultrasound contrast agents in the blood significantly reduces the threshold for ultrasound-induced premature cardiac contractions.

To further test the cavitation hypothesis, we measured cavitation activity in the murine heart in vivo with a passive cavitation detector (PCD). We used a 5 MHz focused transducer as a passive listening device of acoustic signals. We performed experiments with adult anesthetized mice. Boluses of either a contrast agent (Optison®) or saline were delivered via tail vein injections. Pulsed ultrasound exposures were performed at 200 kHz with pulse durations of 1 ms and peak negative pressures ranging between 0.1 and 0.25 MPa. Using the PCD, we quantified acoustic emissions associated with cavitation by the root-mean-square (rms) of the PCD output. For a range of exposure conditions, the extent of cavitation activity was correlated with the likelihood of producing a premature cardiac contraction.

In the presence of Optison®, premature beats were produced in all of the mice exposed to ultrasound. Most importantly, both the number of premature beats and the rms of PCD signal increased with increasing pressure amplitude. On the contrary, none of the animals injected with saline developed premature beats nor was significant cavitation activity measured with the PCD. A direct correlation between the amplitude of the PCD output and the likelihood of producing a premature beat (Figure 1) supports the hypothesis of cavitation as a mechanism for ultrasound-induced premature beats.

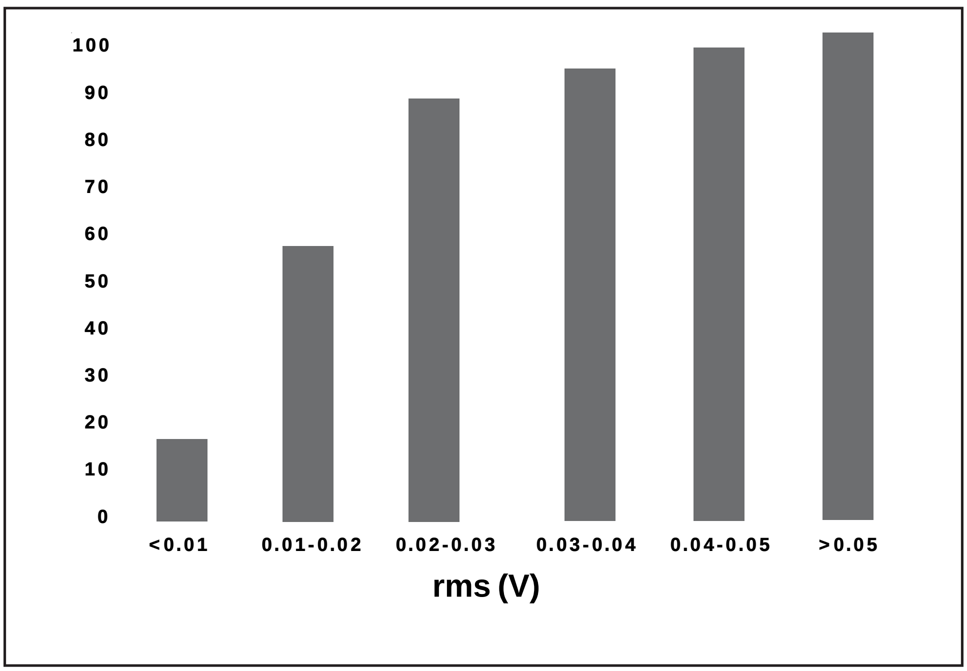


Figure 1. Correlation between the rms of the PCD output and percentage of ultrasound pulses producing a premature beat. Data were collected from n = 10 mice injected with Optison®. Pressure amplitudes of the ultrasound pulse ranged between 0.1 and 0.25 MPa.

Education

Advanced Biomedical Ultrasound (BME 453). This course investigates the imaging techniques applied in state-of-the-art ultrasound imaging and their theoretical bases. Topics include linear acoustic systems, spatial impulse responses, the k-space formulation, methods of acoustic field calculation, dynamic focusing and apodization, scattering, the statistics of acoustic speckle, speckle correlation, compounding techniques, phase aberration correction, velocity estimation, and flow imaging.

Biomedical Ultrasound (BME 451). The physical basis for the use of high-frequency sound in medicine (diagnosis, therapy, and surgery) and biology. Acoustic properties of tissues, sound propagation in tissues, including linear processes as well as finite amplitude sound propagation, and the development of shock waves; interactions of ultrasound with gas bodies, leading to the phenomenon of acoustic cavitation; thermal and non-thermal biological effects of ultrasound ultrasonography, dosimetry, radiation diathermy, thermal surgery, and lithotripsy.

Biosolid Mechanics (BME 483). This course applies engineering mechanics to biological tissues including muscle, soft tissue, cell membranes, and bone. Students learn about realistic modeling of biological structures, including the heart, blood vessels, and the skeleton. The course covers both experimental and computational methods and material models.

Fundamentals of Acoustical Waves (ECE 432). Introduction to acoustic wave propagation. Topics include acoustic wave equation, energy and momentum transmission through infinite fluid media, reflection and transmission at boundaries, radiation from points spheres, pistons, plane cylindrical and spherical wave propagation, diffraction and beam forming, and scattering.

Elasticity (ME449). Analysis of stress and strain, equilibrium, compatibility, elastic stress-strain relations, material symmetries, torsion and bending of bars, plane stress and plane strain, and stress functions. Applications to half-plane and half-space problems, wedges, and notches. 3D problems via potentials.

Finite Elements (BME 486). This course provides a thorough grounding on the theory and application of linear finite element analysis in solid mechanics and related disciplines. Topics: structural matrix analysis concepts and computational procedures, shape functions and element formulation methods, variational methods, weighted residual methods and Galerkin techniques, isoparametric elements, error estimation and convergence, and global analysis aspects.

Medical Imaging Systems (ECE 452). An introduction to the principles of X-ray, CT, PET, MRI, and ultrasound imaging. The emphasis is on providing linear models of each modality, which allows linear systems and Fourier transform techniques to be applied to analysis problems.

Microhydrodynamics (BME 466). This course develops insight into the motion of small particles in a viscous fluid. Such problems are encountered in biology, biotechnology, and composite materials processing. Specific topics include flow past spheres and arbitrary bodies, (thermally driven) motion of bubbles and drops, electrokinetic flows, and lubrication theory.

Nonlinear Finite Element Analysis (BME 487). Theory and application of nonlinear finite element analysis (FEA) with a focus on applications in fluid mechanics. Quick review of basic FEA and generalization to nonlinear situations. Review of fluid mechanics (at the undergraduate level). Linearization and iterative techniques. Illustrations from classic fluids problems with extension to modern problems.

VLSI Signal Processing (ECE 492L). Analysis, design, and implementation of signal processing systems for communications and multimedia. Using state-of-the-art tools and technologies, the course surveys algorithms, architectures, and VLSI implementations of complex signal processing blocks, paying particular attention to performance, area, and energy efficiency. Modern design flow, from algorithm transformation, automatic (and custom) logic synthesis and optimization, circuit and physical design, and timing analysis and verification, for high performance, small area, and low power.

Biomedical Optics (BME 492). This course introduces students to major diagnostic methods in biomedical optics. Currently, the course emphasizes spectroscopy (absorption, fluorescence, Raman, elastic scattering), photon migration techniques (steady-state and time-resolved), and high-resolution subsurface imaging (confocal, multi-photon, optical coherence tomography). Essential methods of multivariate data analysis are taught in the context of spectroscopy.

All courses are not offered each semester. Some courses have prerequisites. See the official University of Rochester bulletin for exact course information.

Third Tissue Elasticity Conference Sessions

The Third International Conference on the Ultrasonic Measurement of Tissue Elasticity was once again co-sponsored by the RCBU and the University of Texas. Jeff Bamber, of The Institute of Cancer Research, Sutton, Surrey, UK hosted the event at Lake Windermere, Cumbria, UK. Researchers from all over the world attended the conference.

Session TUT: Tutorial: Imaging of Cardiovascular Elasticity
Chair: F Duck, UK

Cardiovascular Deformation Imaging - Part I: Vascular; Part II: Cardiac. CL de Korte, University Medical Center Radboud, Nijmegen, The Netherlands, and J D'hooge, Catholic University of Leuven, Leuven, Belgium.

Session MMT: Mechanical Measurement Techniques for Tissues
Chair: E Mazza, Switzerlan; Co-Chair: S Levinson, USA

The Effects of Deformation on the Young's Modulus Measurement by Two Indentors of Different Sizes—a Simulation Study. APC Choi, Y Zheng., The Hong Kong Polytechnic University, Hong Kong, China.

Ultrasound Critical-Angle Reflectometry: Measuring Velocities In Hard And Soft Anisotropic Tissues. PP Antich, et al. University of Texas Southwestern Medical Center, Dallas, TX.

A Device for the Assessment of Nonlinear Viscoelastic Material Properties of Soft Tissues In Vivo. E Tönük, Middle East Technical University, Ankara, Turkey.

Assessment Of Nonlinear Viscoelastic Material Properties of Soft Tissues of Residual Limbs of Trans Tibial Amputees. E Tönük, et al. Middle East Technical University, Ankara, Turkey.

Session SIP-1: Signal and Image Processing - I
Chair: W Walker, USA; Co-Chair: R Maurice, Canada

Strain Estimation Using Spectral Cross-Correlation: Initial Results Using Parametric Methods. K Hoyt, et al., Drexel University, Philadelphia, PA.

A New Time Delay Estimator for Tissue Elasticity Imaging. F Viola, WF Walker, University of Virginia, Charlottesville, VA.

2D Strain Estimation Algorithm - Initial Results. E Brusseau, et al., CREATIS, Villeurbanne, France.

Tissue Strain Imaging Using a Wavelet-Based Peak Search Algorithm. H Eskandari, SE Salcudean, University of British Columbia, Vancouver, BC, Canada.

Session MIP-1: Methods for Imaging Elastic Tissue Properties - I
Chair: M Fink, France; Co-Chair: T Shiina, Japan

The Supersonic Shear Imaging Technique Applied to Nonlinear Properties of Soft Tissues. S Catheline, et al., Laboratoire Ondes et Acoustique, E.S.P.C.I., Paris, France.

Dynamics of Soft Tissue In Response to Impulsive Acoustic Radiation Force with Clinical Applications. ML Palmeri, et al., Duke University, Durham, NC.

Vibration Sonoelastographic Imaging Using a Phase-Locking Technique. A Iqbal, et al., University of Dundee, Dundee, Scotland, UK.

Viscoelasticity Imaging Based On Hysteresis Analysis under Quasi-Static Deformation. N Nitta[1], T Shiina[2]. [1]National Institute of Advanced Industrial Science & Technology (AIST), Tsukuba, Japan; [2]University of Tsukuba, Tsukuba, Japan.

Shear Wave Beamforming Using the Acoustic Radiation Force. J Bercoff, et al., Laboratoire Ondes et Acoustique, E.S.P.C.I, Paris, France.

Visualization of Shear Wave Propagation in Biomaterials with Sonoelastography. ZC Wu, KJ Parker, University of Rochester, Rochester, NY.

A Comparison of Methods Of Sonoelastography in Muscle. S Levinson, et al., University of Rochester, Rochester, NY.

Session CAA-1: Clinical and Animal Applications - I
Chair: WE Svensson, UK; Co-Chair: EE Konofagou, USA

Elasticity Imaging May Improve Local Pre-Treatment Staging of Breast Cancers. WE Svensson, et al., Charing Cross Hospital NHS Trust, London, England, UK.

Non-Invasive Vascular Elasticity Can Detect Vascular Disease. WF Weitzel, et al., University of Michigan, Ann Arbor, MI.

Direct Elasticity Measurement of Inferior Vena Cava Thrombi in Rats: Correlation with Ultrasound Strain Measurements and Thrombus Age. JM Rubin, et al., University of Michigan, Ann Arbor, MI.

Application of Transient Elastography to In-Vivo Measurements of Liver Stiffness in Patients with Chronic Hepatitis C. L Sandrin, et al., Echosens SA, Paris, France.

Real-Time Monitoring of Radiofrequency Ablation in Liver with Acoustic Radiation Force Impulse Imaging. BJ Fahey, GE Trahey, Duke University, Durham, NC.

Hifu Prostate Cancer Treatment Monitoring By Elastography. L Curiel1, et al., INSERM, Lyon, France.

Mechanical Behavior of the Human Cervix: An In Vivo Study. E Mazza, et al., Swiss Federal Institute of Technology, Zürich, Switzerland.

Prostate Elastography: Preliminary In Vivo Results. SK Alam, et al. (EE Konofagou, presenting) Riverside Research Institute, New York, NY.

Session FIP-1: Forward and Inverse Problems - I
Chair: JA Noble, UK

Absolute Modulus Imaging Using Ultrasonic Freehand Scanning and Pressure Sensory Data. J Jiang, et al., University of Wisconsin-Madison, Madison, WI.

Elasticity Reconstruction From Displacement And Confidence Measures of Ultrasound Image Sequences. J Li, JA Noble, University of Oxford, Oxford, England, UK.

Inverse Elasticity Reconstruction Based on an Image Similarity-Measure Approach. J Li, et al., University of Oxford, Oxford, England, UK.

Direct And Interative Algorithms For Inverse Problems In Elastography. E Park, AM Maniatty, Rensselaer Polytechnic Institute, Troy, NY.

Using Arrival Times to Recover Shear Wave Speed Parameters in an Anisotropic Medium. D Renzi, J McLaughlin, Rensselaer Polytechnic Institute, Troy, NY.

An Inverse Problem: Localization of Inserts by Correlation Between Finite Element Models and Elastograms. P Trompette, et al., INSERM, Lyon, France.

Influence of Tissue Viscosity on Wave Propagation Characteristics in Bounded Regions. JGG Dobbe, et al., University of Amsterdam, Amsterdam, The Netherlands.

Plane-Wave Decomposition for an Exact Reconstruction of Transversal Isotropic Properties in Steady-State Dynamic Elastography. R Sinkus, et al.,Philips Research, Hamburg, Germany.

Session CAA-2: Clinical and Animal Applications - II
Chair: WF Weitzel, USA Co Chair: A Sarvazyan, USA

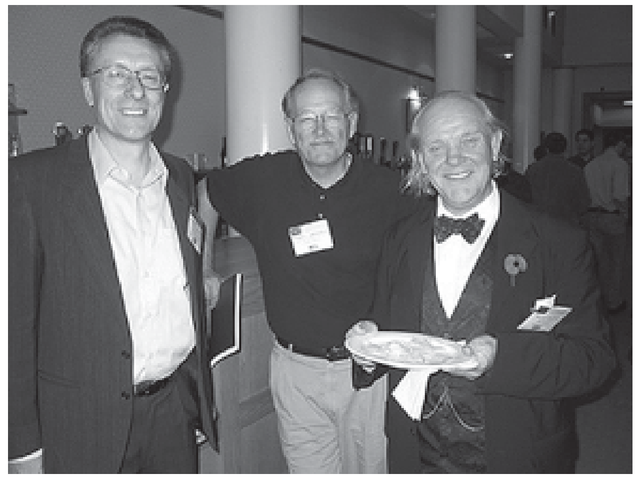
A New Animal Model for In Vivo Elastography. K Hoyt, et al., Drexel University, Philadelphia, PA; Thomas Jefferson University, Philadelphia, PA.

Strain Processing of Intraoperative Ultrasound Images of Brain Tumours. J Bang, et al., SINTEF Health Research, Trondheim, Norway.

Intra-Operative Ultrasound Elastography and Registered Magnetic Resonance Imaging of Brain Tumours; A Feasibility Study. A Chakraborty, et al., Royal Free & University College Hospital Medical School, London, England, UK.

Preliminary Evaluation of Breast Disease Diagnosis Based On Real-Time Elasticity Imaging. T Matsumura, et al., Hitachi Medical Corporation, Chiba, Japan.

New Elastographic Algorithm for In Vivo Study of Mechanical Behavior of Skin. Y Mofid, et al., LUSSI, Tours, France.



Jeff Bamber, host, UK; Jim Greenleaf, USA; Dr. Allan Chapman, guest speaker, UK

Session MPT: Mechanical Properties of Tissues
Chair: G Cloutier, Canada Co-Chair: R Souchon, France

On the Transverse Anisotropy of Human and Bovine Calcified Tissues. JL Katz, et al., University of Missouri-Kansas City, Kansas City, MO.

Analysis of Blood Clot Formation Using Transient Elastography. JL Gennisson, et al., University of Montréal Hospital, Montréal, Québec, Canada.

Intrinsic Limitations in Differential Diagnostics Based on Quantitative Elastography. A Sarvazyan, Artann Laboratories, Lambertville, NJ.

Session SIP-2: Signal and Image Processing - II
Chair: S Emelianov, USA Co-Chair: MM Doyley, USA

Time Domain Cross Correlation with Prior Estimates. R Zahiri-Azar, SE Salcudean, University of British Columbia, Vancouver, BC, Canada.

Direct Strain Measurement Based on an Autocorrelation Method. C Sumi, Sophia University, Tokyo, Japan.

Improved Elastographic Signal-to-Noise Ratio Using Coded Excitation. R Souchon, et al., INSERM, Lyon, France.

Systematic Error Can Dominate Image Noise in Strain Measurements. CX Jia, et al., Boston University, Boston, MA.

Session MIP-2: Methods for Imaging Elastic Tissue Properties - II
Chair: KJ Parker, USA Co-Chair: N Miller, UK

A Novel Haptic Sensor Actuator System for Palpation Imaging Based on Ultrasound Elastography. W Khaled, et al., Ruhr-University, Bochum, Germany.

Mechanism for Human Detection of Elastic Lesions in Simulated B-Mode Movies During Palpation. N Miller, J Bamber, Institute of Cancer Research, Sutton, Surrey, England, UK.

Shear Wave Elasticity Imaging with the Use of Time Reversal Acoustics. A Sarvazyan, A Sutin, Artann Laboratories, Lambertville, NJ.

Non-contact Ultrasound Indentation System for Measuring Tissue Material Properties Using Water Beam. M Lu, et al., The Hong Kong Polytechnic University, Hong Kong, China.

In Vitro Imaging of Hifu-Induced Lesions in Bovine Livers Using Three Dimensional Sonoelastography. M Zhang, et al., University of Rochester, Rochester, NY.

Session AA: Alternative Applications
Chair: JF Greenleaf, USA Co Chair: J D'hooge, Belgium

Sonomyography Analysis of the Morphological Changes of Forearm Muscles in Action. Y Zheng, Xin Chen, The Hong Kong Polytechnic University, Hong Kong, China.

Thermal Properties Reconstruction Technique Based on Temperature Measurement. C Sumi, Sophia University, Tokyo, Japan.

Thermal Lesion Monitoring Using Miniaturized Image-Treat Arrays. IRS Makin, et al., Guided Therapy Systems, Mesa, AZ.

Tissue Displacement and Strain Patterns During Acupuncture Follow Connective Tissue Planes. EE Konofagou, et al., Columbia University, New York, NY.

Combined Ultrasound, Photoacoustic and Elastcity Imaging. S Emelianov, et al., The University of Texas at Austin, Austin, TX.

Session INS: Instrumentation
Chair: Y Zheng, China Co Chair: RM Schmitt, USA

Development of High Bandwidth Transducers Using Injection-Molded 1-3 Low Pitch Composites: A Numerical Study. RM Schmitt, et al., Winprobe Corporation, North Palm Beach, FL.

Development of an Ultrasound Research Platform. WG Scott, et al., WinProbe Corporation, North Palm Beach, FL.

An Actively Shielded Electromagnetic Transducer for MR-Elastography Dedicated to Mammography. H Hörning, et al., Philips Medical Systems, Hamburg, Germany.

Session CVE: Cardiovascular Elasticity
Chair: CL de Korte, The Netherlands Co Chair: H Kanai, Japan

Transcutaneous Measurement of Myocardial Viscoelasticity. H Kanai, Tohoku University, Sendai, Japan.

Adapting the Lagrangian Speckle Model Estimator For Endovascular Elastography: Theory and Validation With Simulated Radio-Frequency Data. R Maurice, et al., University of Montréal Hospital Research Center, Montréal, Québec, Canada.

Investigation of "Ring Resonant Frequency" for Estimation of Arterial Elasticity. X Zhang, JF Greenleaf. Mayo Clinic College of Medicine, Rochester, MN.

Characterization of Vulnerable Coronary Plaque by Strain Power Image. T Shiina, et al., University of Tsukuba, Tsukuba, Japan.

Clinical Evaluation of 3D Intravascular Ultrasound Palpography for Vulnerable Plaque Detection. AFW van der Steen, et al., Erasmus MC, Rotterdam, The Netherlands.

Certificate presentation to Jeff Bamber, host, UK; by Jonathan Ophir and Kevin Parker, conference organizers

Robust Assessment of Arterial Plaque Composition In Vivo Using A Parametric Plaque Model-Based Young's Modulus Reconstruction Method. RA Baldewsing, Erasmus MC, Rotterdam, The Netherlands.

A New Method for Two-Dimensional Myocardial Strain Estimation by Ultrasound: A Comparison with Sonomicrometry In Vivo. S Langeland, et al., Catholic University Leuven, Leuven, Belgium.

Two-Dimensional Functional Information Can Be Used For Automated Left-Ventricular Segmentation. EE Konofagou, TC Pulerwitz, [1]Columbia University, New York, NY.

Session FIP-2: Forward and Inverse Problems - II
Chair: PE Barbone, USA Co Chair: J McLaughlin, USA

Simulation Study of Reconstruction of Shear Modulus, Density, and Poisson's Ratio Distributions. C Sumi, Sophia University, Tokyo, Japan.

Influence of Viscosity on Shear Waves Induced By the Acoustic Radiation Force. J Bercoff, et al.,, Laboratoire Ondes et Acoustique, E.S.P.C.I, Paris, France.

The Inverse Problem of the Shear Wave Propagation: Recovering Both Shear Modulus and Viscosity Images from Supersonic Shear Imaging Data. J Bercoff, et al., Laboratoire Ondes et Acoustique, E.S.P.C.I.,Paris, France.

Enhancing the Performance of Modulus Elastograms. MM Doyley, et al., Dartmouth Medical School, Hanover, NH.

Transient Elastography: Algorithms and Models. J McLaughlin, et al., Rensselaer Polytechnic Institute, Troy, NY.

Session MIP-3: Methods for Imaging Elastic Tissue Properties - III
Chair: R Sinkus, Germany Co Chair: E Brusseau, France

Imaging Localized Viscoelastic Properties Using Harmonic Motion Imaging. EE Konofagou, TP Harrigan, Columbia University, New York, NY.

Poisson's Ratio Imaging and Poroelastography in Biological Tissues: A Feasibility Study. R Righetti, et al., The University of Texas Medical School, Houston, TX.

A Method For Generating Permeability Elastograms Using Poroelastography. R Righetti, et al., The University of Texas Medical School, Houston, TX.

Towards a Model-Based Poroelastic Imaging Method. G Berry, et al., Institute of Cancer Research, Sutton, Surrey, England, UK.

Monitoring Of Hifu Lesions Using Supersonic Shear Imaging: A Unique Therapy and Imaging System. J Bercoff, et al., Laboratoire Ondes et Acoustique, E.S.P.C.I, Paris, France.

Session CET: Complementary Elasticity Imaging Techniques
Chair: AFW van der Steen, The Netherlands Co Chair: C Sumi, Japan

3D In Vivo Liver MR-Elastography. R Sinkus[1], H Hörning[2], L ter Beek[3], M Dargatz[1] and B Van Beers[4]. [1]Philips Research, Hamburg, Germany; [2]Philips Medical Systems, Hamburg, Germany; [3]Philips Medical Systems, Brussels, Belgium; [4]St. Luc, Brussels, Belgium.

Determination of Anisotropic Elasticities of In Vivo Skeletal Muscle Using A Geometric Analysis Of MR-Elastography Wave Patterns. S Papazoglou, et al., Institute of Radiology-Charité, Berlin, Germany.

Measuring The Mechanical Properties of Small Biological Tissues Using Micro Magnetic Resonance Elastography (μMRE). SF Othman, et al., University of Illinois at Chicago, Chicago, IL.

Session PTO: Phantoms and Test Objects
Chair: EL Madsen, USA

Fast Generation of 3d Synthetic RF Data of Nonlinearly Elastic Objects for Speckle Tracking Performance Evaluation. RQ Erkamp, et al., University of Michigan, Ann Arbor, MI.

Tissue-Mimicking Spherical Lesion Phantoms for Elastography with and Without Ultrasound Refraction Effects. EL Madsen, et al., University of Wisconsin-Madison, Madison, WI.

Tissue-Mimicking Anthropomorphic Breast Phantoms for Ultrasound and MR Elastography. EL Madsen, et al., University of Wisconsin-Madison, Madison, WI.

Design and Characterisation of a Compliant Wall Vascular Phantom of Varying Elasticity for Ultrasound Investigation of Arterial Wall Motion (AWM). J Dineley, P Hoskins, University of Edinburgh, Edinburgh, Scotland, UK.

Development of a New Tissue-Equivalent Gel for Wall-Less Flow and Wall Motion Phantoms. TL Poepping, et al., University of Edinburgh, Edinburgh, Scotland, UK.

Session POS: Posters
Chair: TA Krouskop, USA

A Study of Vibration Characteristics for Ultrasonic Elasticity Imaging. J Park, et al., Daejin University, Pocheon, Kyeonggi, Korea.

Computer-Based Vibrational Viscoelastoc Measurement of Soft Tissues. EM Timanin, EV Eremin, Institute of Applied Physics RAS, Nizhny Novgorod, Russia.

Two-Dimensional Elastic Modulus Distribution Reconstruction Based on a Modified Three-Dimensional Finite-Element Model. M Yamakawa, T Shiina, University of Tsukuba, Tsukuba, Japan.

An Arterial Wall Motion Test Tool to Assess Philips AWM Software. SJ Hammer, et al., The University of Edinburgh, Edinburgh, Scotland, UK.

Intravascular Ultrasound Palpography for Determining the Age of a Thrombus: An Animal Study In Vivo. JA Schaar, et al., Erasmus MC, Rotterdam, The Netherlands.

Optical Flow Tissue Tracking Using Real-Time 3D Ultrasound. P Jordan, et al., Harvard University, Cambridge, MA.

Feasibility of Skin Surface Elastography by Tracking Surface Topography. L Coutts, et al., Institute of Cancer Research, Sutton, Surrey, England, UK.

Description of a New Iterative Algorithm for Scaling Factor Estimation. J Fromageau, et al., CREATIS, Lyon, France.

Gaussian Modeling of Dispersive Media: Application to Calcified Tissues. D Hazony, JL Katz, Case Western Reserve University, Cleveland, OH.

Extraction of Modulus from the Osmotic Swelling of Articular Cartilage Measured Using Ultrasound. H Niu, et al., The Hong Kong Polytechnic University, Hong Kong, China.

Osmotically-Induced Shrinkage and Swelling Behavior of Normal Bovine Patellar Articular Cartilage In Situ Monitored by Ultrasound. Q Wang, Y Zheng, The Hong Kong Polytechnic University, Hong Kong, China.

Effect of Saline Concentration on Sound Speed on Articular Cartilage. S Patil, Y Zheng, The Hong Kong Polytechnic University, Hong Kong, China.

Skin Elasticity Measurement Based on a 20 MHz Ultrasound Biomicroscope. Y Huang, Y Zheng, The Hong Kong Polytechnic University, Hong Kong, China.

Ultrasonic Measurement of In-Vivo Strain of Surgically Repaired Achilles Tendon Under Isometric Contraction. J Chan et al.,The Hong Kong Polytechnic University, Hong Kong, China.

Effects of Internal Discontinuities On Strain Elastograms. TA Krouskop, et al., Baylor College of Medicine, Houston, TX; The University of Texas Medical School, Houston, TX.

Biomechanical Properties of Corneal Tissue Determined by Applanation and Thin Shell Model. J Liu, C Roberts, The Ohio State University, Columbus, OH.

Imposing Physical Constraints to Yield Accurate and Unbiased Displacement Estimates. NH Gokhale, et al., Boston University, Boston, MA.

Analysis of 3D Left Ventricular Wall Motion Using Tissue Doppler Imaging. AF Kolen et al.,University Hospital Maastricht, Maastricht, The Netherlands.

Session EEX: Equipment Exhibit
Chair: N Bush, UK

Hitachi Medical Corporation, Kashiwa, Japan

Medison Corporation, Seoul, Korea

Precision Acoustics, LTD, Dorchester, Dorset, England, UK

Patents and Software

The RCBU is continually working on novel concepts in ultrasound research. A collection of patents and software programs that originated at the Center are summarized on the next few pages. For more information, technology transfer arrangements, or licensing agreements for a specific patent, call the University of Rochester Technology Transfer office at (585) 275-3998, or as indicated below.

System for Model-Based Compression of Speckle Images

Ultrasound images contain speckle. These high-spatial patterns are ill-suited for compression using conventional techniques, particularly by JPEG, which is designed for photographic images with regions of smooth or negligible intensity variations. Conventional compression techniques fail to provide high quality reproductions with high compression ratios. This combination is desirable for telemedicine and other applications where the available bandwidth or storage constraints create a need for high quality and high compression of ultrasound images. U.S. Patent No. 5,734,754 issued March 31, 1998, describes a system for compression of speckle images.

Finite Amplitude Distortion-Based Inhomogeneous Pulse Echo Ultrasonic Imaging

A method and system for imaging a sample. The method includes the steps of generating an ultrasonic signal, directing the signal into a sample, determining which signal is distorted and contains a first order and higher order component signals at first and higher frequencies respectively. The received distorted signal is processed, and an image is formed, and then displayed, from one of the higher order component signals of the received distorted signal. U.S. Patent No. 6,206,833 was issued to Ted Christopher on March 27, 2001. For further information contact Eugene Cochran, Research Corporation Technologies, at (520) 748-4461.

Blue Noise Mask

Medical images are sometimes printed on devices that have limited output states. For example, laser printers can render black or white but not shades of gray. Halftone methods render gray as patterns of black and white dots. The Blue Noise Mask is a halftone screen method for digital or photographic rendering of images. The Blue Noise Mask produces the fastest possible rendering of medical images with an artifact-free halftone pattern. The fax transmission of medical images can also be made faster and with higher quality by utilizing the Blue Noise Mask and new tonefac algorithm. The Blue Noise Mask invention received numerous patents, including: U.S. Patent Nos. 5,708,518; 5,726,772; 5,111,310; 5,477,305; and 5,543, 941. This patented technology has been accepted by over 15 U.S. companies and organizations including: Seiko, Epson, Hewlett-Packard, Tektronix, and Research Corporation Technologies. For further information contact Eugene Cochran, Research Corporation Technologies, at (520) 748-4461.

Thin-Film Phantoms and Phantom Systems

Phantoms for testing and measuring the performance of ultrasonic imaging systems have regions of precisely controlled scattering or echogenicity that contain subresolvable scatterers. The phantoms can reveal the combined influences of all the stages in the imaging chain in terms of modulations, transfer function, and resolution limits as well as other artifacts and defects in the system, such as aliasing and frequency response, which cannot be evaluated with conventional ultrasound phantoms. Halftone masks may be used to produce regions of precisely controlled subresolvable scatterers to be used for gray-scale evaluation of the imaging system by producing speckle images of different echogenicity. The thin-film sheets are thinner than the thickness of the ultrasonic beam and enable propagation of the beam in the plane of the sheets to the patterns, which may be located at different depths. The sheets may be made of piezoelectric material having electrodes across which varying electrical signals are applied to displace the sheets, thereby simulating movement of objects for Doppler measurements. U.S. Patent No. 5,756,875 was granted on May 26, 1998, to coinventors Daniel B. Phillips and Kevin J. Parker.

An Inexpensive Wide-Bandwidth Hydrophone for Lithotripsy Research

Probing the acoustic field of extracorporeal lithotripters places several demands upon conventional hydrophones. “Needle” hydrophones, while better able than “membrane” hydrophones to withstand the cavitation-related damage inherent in lithotripter measurements, nevertheless lack their superior high-frequency response. Even the most popular membrane hydrophones do not have sufficient sensitivity at high frequencies to resolve the rapid rise times (1-20 ns) of waveforms that may occur at a lithotripter focus. To overcome these limitations, we have developed a membrane-type hydrophone that costs hundreds (not thousands) of dollars and has disposable active elements that can be replaced easily when damaged. These elements, of 6 mm PVDF copolymer film, incorporate an electrode pattern that assures identical sensitivity from one element to the next, obviating the need for recalibration after replacement of the element. On-board conditioning electronics increase the effective bandwidth of the hydrophone to over 125 MHz and provide clipping of the undesirable electromagnetically induced transients of spark-discharge lithotripters. For more information, contact Carr Everbach at (215) 328-8079.

System and Method for 4D Reconstruction and Visualization

From raw image data obtained through magnetic resonance imaging or the like, an object is reconstructed and visualized in four dimensions (both space and time). First, the first image in the sequence is divided into regions through statistical estimation of the mean value and variance of the image data and joining of picture elements (voxels) that are sufficiently similar. Then, the regions are extrapolated to the remainder of the images by using known motion characteristics of components of the image (e.g., spring constants of muscles and tendons) to estimate the rigid and deformational motion of each region from image to image. The object and its regions can be rendered and interacted within a four-dimensional virtual reality environment. US Patent No. 6,169,817 was issued to co-inventors Kevin J. Parker, Saara S. M. Totterman, and Jose Tamez-Pena.

The Acoustic Filter

The acoustic filter is a system for reducing post-cardiopulmonary bypass encephalopathy due to microembolization of the brain of a patient with gaseous microbubbles (less than 40 microns in diameter). This invention is recommended for use during open heart surgery with a cardiopulmonary bypass machine bypassing a stream of blood from the patient through an ultrasonic traveling wave that propagates across the stream without reflection and sweeps the blood clean of the microbubbles without inducing blood cell trauma. The blood passes through a chamber between an input port and a filtrate exit port. The microbubbles are carried by the traveling wave to a waste exit port in the chamber downstream of the input port. To prevent establishment of resonance conditions, reflections, and traveling waves, the chamber may be submerged in a liquid bath and a body of acoustically absorbed material disposed at an end of the chamber opposite to the end into which the ultrasonic beam is projected. U.S. Patent No. 5,334,136 has been issued to co-inventors Karl Schwarz, Richard Meltzer, and Charles Church.

Multiple Function Infant Monitor

Piezoelectric polymer sheets made of PVDF, placed on the floor of a crib, can output voltage that provides information about the heart and breathing rates of an infant in the crib. Using external detection and conditioning with the PVDF sheet, we have constructed a low-cost PVDF infant health monitor. The monitor can alert parents, with the aid of a remote alarm, to a declining heart and/or respiration rate indicative of the onset of sudden infant death syndrome. US Patent No. 5,479, 932 has been issued for this invention. For more information, contact Carr Everbach (215) 328-8079.

Apparatus for Bone Surface-Based Registration

A novel technique has been developed that could be used for neurosurgical and other applications. The device is entitled “Apparatus for Bone Surface-Based Registration of Physical Space with Tomographic Images for Guiding a Probe Relative to Anatomical Sites on the Image.” The co-inventors of this technique are from Vanderbilt University and the University of Rochester: W. A. Bass, R. L. Galloway, Jr., C. R. Maurer, Jr., and R. J. Maciunas. US Patent No. 6,106,464 was issued on August 22, 2000.

Sonoelasticity Imaging Estimators

Sonoelasticity imaging is a novel method for assessing the stiffness, or elastic constants, of tissues. This combination of externally applied vibration and new Doppler imaging techniques was pioneered at the University of Rochester by Robert M. Lerner and Kevin J. Parker in 1986, following earlier work by Dr. Lerner on stiffness and compressibility of phantom materials and basic Doppler studies by Dr. Jarle Holen and colleagues. Since sonoelasticity imaging reveals patterns of vibrations within tissues, stiff tumors that may not be accessible to palpation can be imaged regardless of subtle changes in echogenicity. US Patent No. 5,086,775, concerning time and frequency domain estimators for sonoelasticity imaging, has been issued to co-inventors Ron Huang, Robert Lerner, and Kevin Parker.

Linear and Nonlinear Acoustic Field Propagation Software

We have developed a computational model for the nonlinear propagation of acoustic beams. The physical effects of diffraction, absorption, dispersion, nonlinearity, and planar reflection and refraction are accounted for in an accurate and efficient manner. Descriptions of the novel algorithms accounting for these physical effects have been presented in a series of publications. The model has been compared successfully with theoretical and experimental results. The model has also been used to make predictions about the in vivo performance of biomedical ultrasonic imaging devices and lithotripters. Finally, the model is currently being extended to consider non-axially symmetric source propagation in phase-aberrate media. U.S. patent allowed.

Butterfly Search Technique

We have developed a novel, robust, and accurate blood velocity estimation technique that is implemented by elementary digital signal processing without any transforms, correlation searches, SAD searches, matched filters, or other intensive operations. In this technique, echoes from repeated firings of a transducer are resampled along a set of predetermined trajectories of constant velocity. These are called butterfly lines because of the intersection and crossing of the set of different trajectories at some reference range. The slope of the trajectory on which the sampled signals satisfy a predetermined criterion appropriate for the type of signal in question provides an estimate of the velocity of the target. The search for this trajectory is called Butterfly Search and is carried out efficiently in a parallel-processing scheme. The estimation can be based on the RF echo, its envelope, or its quadrature components. The Butterfly Search on quadrature components has shown outstanding noise immunity, even with relatively few successive scan lines, and was found to outperform all the common time domain and Doppler techniques in simulations with strong noise. The Butterfly Search can overcome many disadvantages faced by present-day techniques, such as the stringent trade-off criterion between imaging resolution and velocity resolution implicit in Doppler techniques, and the need for computations. US Patent No. 5,419, 331 has been issued to co-inventors Kaisar Alam and Kevin Parker.

“Smart” Endotracheal Tube

This invention relates to airway management devices for use in medical emergencies and more particularly to an endotracheal tube apparatus that generates a signal to ensure proper placement of the tube in a patient’s trachea. A flexible tube extends from the patient’s oral or nasal cavity to a distal end within the trachea. An ultrasound transducer is connected to the tube near its distal end, in contact with the forward inner wall at the midpoint of the patient’s trachea. A second ultrasound transducer contacts the forward outer skin surface of the patient’s neck. Either the first or the second transducer can transmit an ultrasound signal provided by ultrasound transducer excitation, to which it is electrically connected. The other transducer serves as a receiver, connected to an ultrasound detector external to the patient.

Also, a process for monitoring the position of an endotracheal tube inserted in a patient uses a flexible tube extending from the patient’s oral or nasal cavity to a distal end and the first ultrasound transducer connected to the tube near its distal end. The first transducer contacts the forward inner wall of the trachea at its midpoint, and a second ultrasound transducer is contacts the forward outer skin surface of the patient’s neck at a position at least partially overlying the position of the first transmitter. US Patent No. 5,785,051 was issued July 29, 1998, to co-inventors Jack Mottley and Randy Lipscher for this invention.

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