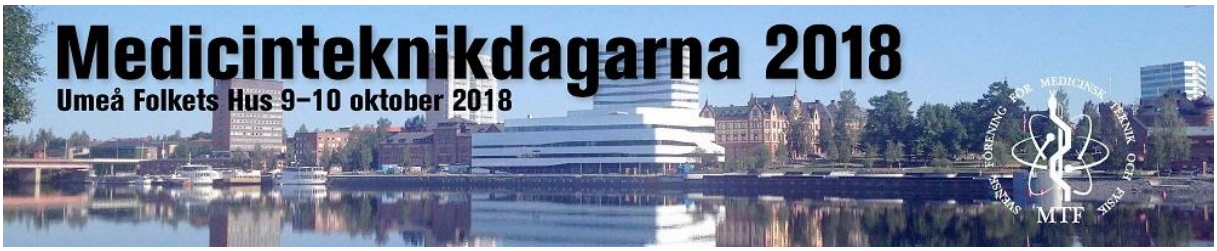

MEDICINSKA BILDER

Tisdag 9 oktober 15.15 – 17.00

Abstract: 122

Evaluating the dosimetric accuracy of radiotherapy treatment planning based on synthetic CTs generated from ZTE and LAVA-Flex MR data

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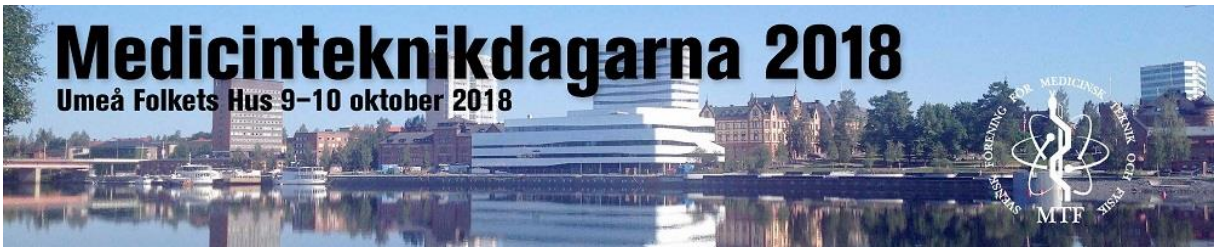
Purpose / Objective
MR images are often used in radiotherapy for delineation of treatment volumes and organs at risk. However, electron density information is also required when performing treatment planning. Traditionally, this information comes from CT images of the patient. If synthetic CT (sCT) images are instead generated from MR images, an MR-only workflow can be achieved. This allows for reduced registration errors, and can for instance also pave the way for individualized treatment based on the progression of the tumor during treatment in a combined MR-LINAC. In this project, we are investigating the generation of sCT images using Zero TE (ZTE) and LAVA-Flex MR images. The dosimetric accuracy when using these sCT images for treatment planning is evaluated.

Materials / Methods
30 male patients with with cancer in the pelvic region were imaged in both a CT scanner and a GE SIGNA 3T PET/MR camera as part of their regular clinical treatment. In addition to the images acquired as part of normal clinical routine, ZTE and LAVA-Flex MR images were acquired. These additional images were used to generate the sCT images. The LAVA-Flex data was used to generate outer body contours, while the ZTE data provided bone information. Fixed Hounsfield Unit values of -1000 and 42 were assigned to air and soft tissues respectively. For bone, inverse linear scaling was used. To avoid errors due to differences in patient positioning, the patient outer contours were matched, with all pixels in the sCTs outside the CT external contour set to the HU value of air, and any air pixels inside the contour set to that of soft tissue. Similarly, all gas pockets inside the patient were set to the value of soft tissue for both CT and sCT images in order to avoid errors due to differences in pelvic gas. Treatment plans were created based on the original unmodified CT images for 11 of the patients. For the evaluated patients, the treatment plans were then re-calculated based on the created sCTs, and the dose distributions of the two plans were compared. Gamma analysis was performed on 3 patients.

Results
The absolute error in average dose to the PTV ranged from 0.03% to 0.91% (mean 0.47%). Gamma analysis using a 1%/1-mm global gamma criteria showed a 92.48% to 100.0% (mean 96.10%) pass rate for the PTV, and 95.89% to 100.0% (mean 98.57%) for the volume receiving dose >15% of the prescribed dose. With a 2%/2-mm global gamma criteria, a pass rate of 100.0% was achieved in both cases.

Conclusions
The results show that sCTs generated from ZTE and LAVA-Flex MR images can be used to calculate treatment plans with good dosimetric accuracy, indicating that it is a viable alternative to CT-imaging as a basis to perform treatment planning. Work is in progress to also assess its viability in the positioning stage of radiotherapy treatment, which would mean that it could completely replace CT-imaging for this type of treatment.



Abstract: 155

Clinical translation of a novel photoacoustic imaging system for non-invasive daignosis of giant-cell arteritis

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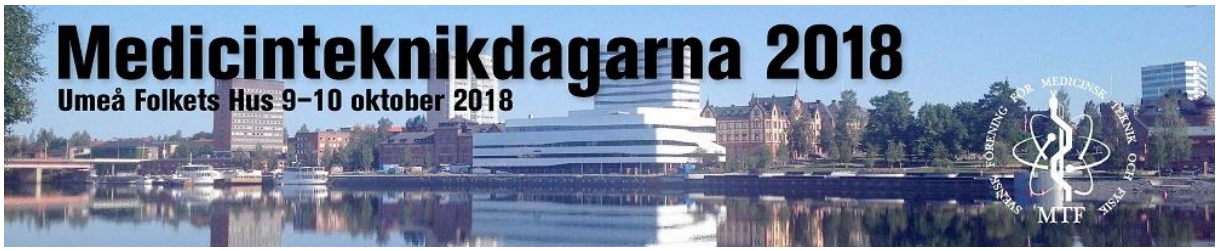
Background, Motivation and Objective;
Photoacoustic imaging (PAI) which converts the absorption of nanosecond laser light pulses in tissue into an ultrasonic signal via thermoelastic expansion, is currently one of the most rapidly emerging non-invasive bioimaging techniques, but has yet not been used in a clinical setting. The objective was to translate PAI into a clinical setting where imaging of the human temporal artery could lead to non-invasive diagnosis of giant cell arteritis (GCA) and to describe the challenges encountered and methods to overcome them.

Statement of Contribution/Methods;
The temporal artery, situated in the temple region, was examined in 7 patients with suspect GCA, both in vivo and ex vivo using a Visualsonics Vevo LAZR (Visualsonics, Toronto, Canada). To obtain the PAI signature of the tissue a multi-wavelength 3D scan was performed at 12 wavelengths (700-940 nm) as well as PAI spectroscopy in 5 nm increments (680-970 nm) at particular regions of interest. The results were compared to that of histology. To adapt PAI to human studies, the transducer was fixed to an adjustable arm to reduce motion artifacts and a stepping motor was used to enable 3D scanning. Risks were evaluated by measuring energy levels and the visual function of the subjects before and after the examinations. Safety precautions were undertaken to prevent injury to the patients and staff. Visual acuity was measured with the Snellen letter chart.

Results, Discussion and Conclusions
We will show representative examples of the PAI spectra obtained from a temporal artery wall in vivo and ex vivo, as well as from the surrounding tissue in vivo. The in vivo spectrum shows the effects of motion artefacts and noise due to interference of blood and other chromophores. The energy levels involved were found to be below limits given in regulatory standards. Eye protectors prevented irradiation of the patient’s eyes, and visual function after the procedure was found not to be affected. The patients reported no discomfort during the investigations. PAI provides images of the temporal artery wall that may be used for the future diagnosis of GCA in humans. The technique could be further refined by addressing the specific problems of motion artefacts and interference from blood and other chromophores. This study paves the way for other clinical applications of PAI.



Abstract: 158

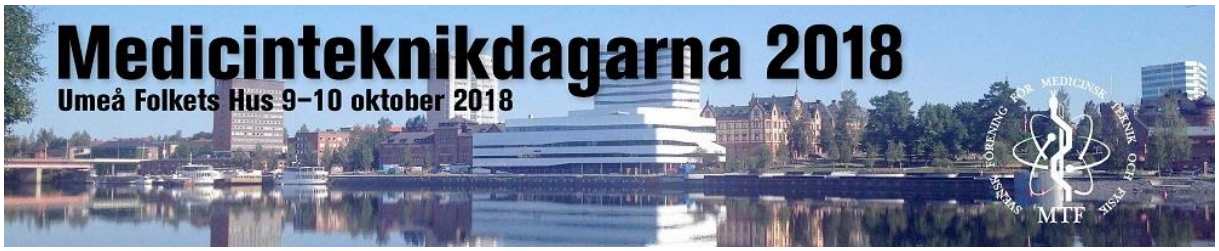
An ultrasound phantom material with unique features: changing viscoelastic properties while keeping the speed of sound constant

*B. Meirza*1, S. Sjöstrand1, M. Evertsson2, I. Svensson1, L. Grassi1, T. Jansson3, M. Cinthio1; 1Lunds Tekniska Högskola, Institutionen för Biomedicinsk Teknik, Lund, 2Lunds universitet, Biomedicinsk teknik, Lund, 3Medicinsk Service, Medicinsk Teknik, Skåne, Lund*

Background, Motivation and Objective;
Realistic phantoms for ultrasound measurements are essential for developing new ultrasound methods and evaluating imaging techniques. To date, several tissue mimicking materials have been proposed. However, to the best of our knowledge, none of these existing materials give the possibility of changing the viscoelastic properties while keeping the speed of sound constant. Here we propose an oil-based phantom material for which the viscoelastic properties can be changed while keeping the speed of sound approximately constant. The aim of this study was to evaluate the novel material.

Statement of Contribution/Methods;
The novel material was made by mixing two commercially existing oil-based gels: 1) styrene-ethylene/butylene-styrene (SEBS) copolymer in mineral oil and 2) Clear ballistic gel. In this study we evaluated the viscoelastic properties, the speed of sound and the density for five ratios (0%, 25%, 50%, 75% and 100%) of SEBS in Clear ballistic gel (five samples for each ratio). The mechanical response of the samples was evaluated through stress relaxation tests. The obtained force-displacement response was then fitted to a standard linear viscoelastic solid model to extrapolate the material parameters such as stiffness and viscosity. The speed of sound was measured using a time of flight method and the density was calculated from mass and volume.

Results, Discussion and Conclusions
The instantaneous stiffness ($R = -0.97$; $p < 10\text{-}14$) and the viscosity ($R = -0.96$; $p < 10\text{-}13$) decreased whereas the density increased ($R = 0.62$; $p < 0.001$) linearly with the ratio between SEBS and Ballistic gel. The speed of sound showed no correlation with the ratio between SEBS and Ballistic gel ($R = -0.04$; $p = 0.72$). In this study, a novel mix of ultrasound phantom materials was developed and characterized. It was shown that the material retained its speed of sound constant while the viscoelastic properties changed linearly with the ratio between SEBS and Clear ballistic gel. SEBS, Clear ballistic gel and its mixtures are stable, easy to use and manufacture, and are versatile. The results suggest that combining SEBS and Clear ballistic gel produces a promising phantom material for ultrasound imaging. The material is potentially useful for manufacturing ultrasound phantoms for development and evaluation of elastographic and photo-acoustic imaging methods.



Abstract: 130

MICE Toolkit – an interactive research tool for image analysis

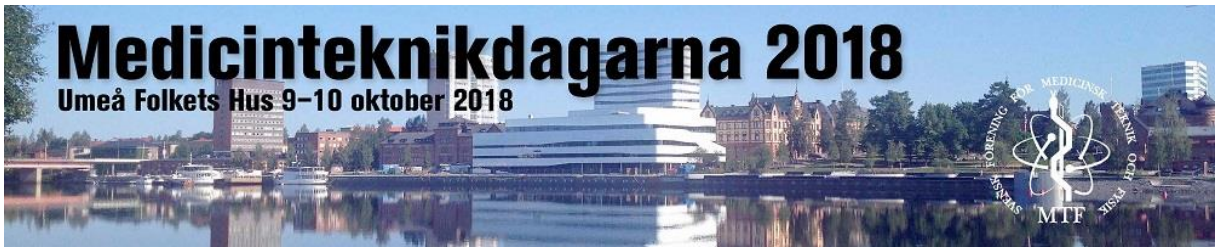
**P. Brynolfsson*, M. Berglund, J. Jonsson, T. Löfstedt, A. Garpebring, T. Nyholm; Umeå Universitet, Inst. för strålningsvetenskaper, Umeå*

Purpose:
Advanced image analysis has become increasingly important in medical research. However, the availability of complete, flexible and user-friendly software is scarce. This leads many researchers to use an array of commercial software in combination with in-house software developed in e.g. MATLAB or Python. The in-house software allows full customization, but is time-consuming to develop, and the code is often difficult to re-use in other projects. The aim of the current project is to develop a software that combines the flexibility of in-house design with the rigor and power of ITK and VTK in a simple and intuitive graphical user interface, making advanced image analysis available to the medical research community. Further, the software should also be suitable for teaching the foundations and advanced applications of medical image analysis to students and interested professionals. Materials &

Methods:
MICE Toolkit is a research tool developed at the Radiation Physics department at Umeå Universitet, recently commercialized through the spin-off company NONPI Medical AB with support from the Swedish Innovation Agency (Vinnova). MICE Toolkit is coded in the .NET framework; the interface is constructed in C#, but certain features use C/C++, such as Elastix, the registration module. Many of the functionalities are based on ITK, and the visualization is based on VTK. The image processing operations are represented by boxes, or nodes, and the inputs and outputs of different nodes can be connected by virtual wires to form a workflow. Image databases can be created by importing DICOM images, and anonymization functions allow the data to be shared securely with collaborators. Images can also be imported into the workflow directly from DICOM, MHD, Nrrd, NIfTI and other image formats. Results can be exported as DICOM, MHD, MATLAB .mat, Excel-files, CSV-files, .stl files and many other file formats. MICE Toolkit also integrates with MATLAB and Python, allowing researchers and students to integrate their own code in any analysis workflow.

Results:
The software can be used to e.g. perform rigid and non-rigid registrations, filter images using any of the Simple ITK filters, create masks, perform arithmetic operations, calculate statistical properties, perform texture analysis, analyse radiotherapy data using gamma and DVH, analyse MRI diffusion measurements, standardized uptake values (SUV) from PET images, and create dynamic contrast-enhanced MRI (DCE-MRI) analysis workflows, and much more. Workflows can be run in batches to apply any analysis workflow on a cohort of patients. The visualization module allows e.g. multiplanar reconstructions, reslicing, fusions of multiple image sets, creating masks, and 3D-visualization with shading. The software allows exporting images as well as animations.

Conclusions:
The software greatly simplifies the setup and design of image analysis workflows, which can be applied to individual patients or sets of patients organized in image databases. With the wealth of filters and functions, and the option to integrate MATLAB and Python code, the software is well suited for advanced image analysis research, as well as for image analysis teaching purposes. The software can be downloaded from , where extensive documentation and tutorial videos can also be found.



Abstract: 70

Ultrasound-based Imaging of Motor Units in Skeletal Muscle Tissue

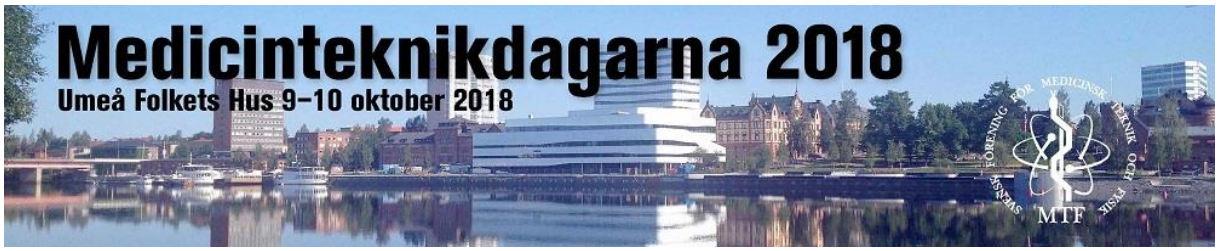
**R. Rohlén*; Radiation Sciences, Umeå University, Radiation Sciences, Umeå University, Umeå*

Background
Parkinson's disease, multiple sclerosis (MS) and amyotrophic lateral sclerosis (ALS) are all neuromuscular diseases affecting people around the world. Neuromuscular diseases hinder muscle function and may be the outcome of damage and dysfunction of the smallest voluntarily activatable units in skeletal muscle tissue, the so-called motor units (MUs). MUs generate electrical signals and analyzing these signals gives a basis to assess and diagnose MUs. The signals are captured using needle electromyography, which is an invasive and non-imaging method. Here, we show ultrasound-based imaging of MUs, via an ultrasound-based spatiotemporal decomposition framework.

Material and Methods
To measure a transient muscle contraction mechanism, we need high frame rate and therefore use ultrasound plane wave imaging. To quantify the motions, we estimate a sequence of tissue velocity images, serving as input to a statistical blind source separation method, and thereby isolate functional components from surrounding tissue motions. Based on this framework, we studied both electrostimulated and low force isometric contractions of the biceps brachii muscle in five healthy subjects. Furthermore, we evaluated framework performance on simulated data.

Results
We show that we can find spatial territories of putative MUs under both electrostimulation and voluntarily isometric contraction. Also, the framework shows the ability to recover the true simulated spatial territories and mechanical waveforms.

Conclusions
We have taken the first step towards ultrasound-based imaging of MUs, via a framework using the spatiotemporal decomposition of image sequences under isometric contraction. Up until this point, methods for imaging MUs does not exist, and this work gives a basis to study and understand the spatiotemporal dynamics of MUs and thereby enhancing assessment and diagnostics of various neuromuscular diseases.



Abstract: 139

In vivo muscle architecture of hemiplegic post-stroke patients: Comparison of ultrasound and diffusion tensor imaging

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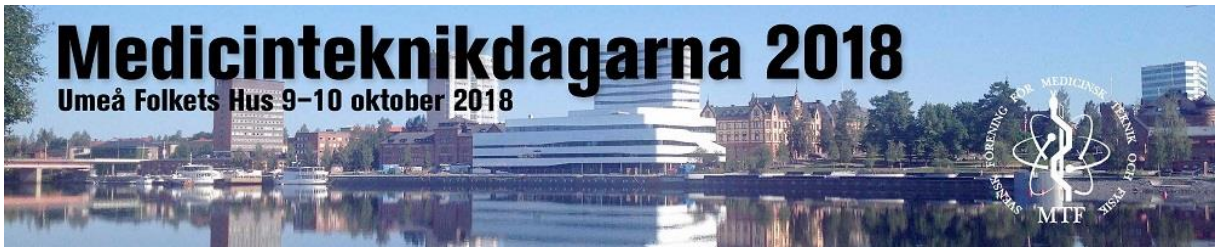
Introduction
The force generating capacity of a skeletal muscle depends on the muscle architecture parameters, e.g., fascicle lengths (FL), pennation angle (PA) and thickness (tm), which can be altered due to pathologies. In vivo measurements of muscle architecture commonly use ultrasound (US), which typically provides only 2D images and is not always feasible to assess deep muscles. Diffusion tensor imaging (DTI) based approaches to reconstruct muscle fascicles have evolved as alternative reference standard to investigate 3D muscle morphology. The objective of the study therefore was to quantify muscle 3D morphological parameters from DTI and compare the parameters identified by 2D ultrasound imaging in post-stroke patients. For demonstration, the gastrocnemius, posterior soleus and tibialis anterior were chosen.

Methods
The experimental data are obtained from five hemiplegic stroke survivors (age: 59 ± 15 yrs, height: 173 ±11 cm). Eight markers were placed on the standard bony landmarks of subject's affected leg in both DTI and US acquisitions. The markers were visible in T1 images and also tracked during US acquisition with the Oqus system (Qualisys). The patients were scanned bilaterally using a 3T MRI scanner (Siemens Trio) while lying in a supine position. The T1-weighted images with a voxel size of 0.84 x 0.84 x 5mm and DTI images with a voxel size of 2.5 x 2.5 x 2.5mm (20 gradient directions) were obtained. The US data was measured at the same joint configuration as the DTI acquisitions. The reconstruction of muscle fascicles was consists of several steps (segmentation of muscles, DTI registration, fascicle tracking, and parameter identification) [1]. To compare US and DTI measurements, the US and MR coordinate system were aligned by using the markers to create a transformation matrix.

Results
Averaged over all three muscles, FL measured by US was around 4.2mm (or 17%) bigger than measured with DTI reconstruction. US yielded tm of 1.8mm (or 20%), on average smaller than the DTI results. Only the tibialis anterior tm showed a higher variance of 5.1mm (or 41%). PA measured with ultrasound was, on average, 17.2% (or 36%) smaller than PA measured with DTI. Discussion The comparison of US and DTI parameters showed a sufficient agreement of mean values for FL and tm in post-stroke subjects. However, the differences observed in PA are larger than differences reported by Bolsterlee et al. [1] in healthy subjects. One reason could be that joint alignment was difficult in some patients due to their spasticity.

Conclusion
When choosing an imaging method for in vivo muscle architecture measurements, there is no definite gold standard. While the DTI fascicle reconstruction method of this study has the advantage over US of using 3D data, it comes with some limitations and is in need of further refinement. The techniques presented will be useful in the development of 3D personalized musculoskeletal models to study movement disorders.

References *[1] Bolsterlee et al., Ultrasound imaging of the human medial gastrocnemius muscle: how to orient the transducer so that muscle fascicles lie in the image plane. Journal of Biomechanics, 49(7):1002–1008, 2016.*



Abstract: 154

Automatic detection of healthy arterial wall tissue in vivo using photoacoustic multi-spectral imaging

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Background
Photoacoustic multi-spectral imaging (PAI) can distinguish tissue based on molecular information. To be able to identify different type of tissue in a clinical setting the spectrum of the tissues-of-interest need to be known and the identification protocol as automatic as possible since manual delineation is very time-consuming. The overall objective in a larger study is to develop a method for non-invasive diagnosis of giant cell arteritis (GCA) using PAI. In this sub-study the aim was a) to automatically identify healthy artery walls in in vivo PAI using spectrums obtained from ex vivo PA images of healthy artery walls and b) to decrease spectral noise by implementing motion tracking in alternately acquired ultrasound images.

Material & Methods
Seven patients with suspected GCA (later found negative) were examined with PAI using the Vevo Lazr-X (Visualsonics, Toronto, CA) before surgical removal of one of their temporal arteries. The arteries were then examined ex vivo with PAI and the artery wall spectrums covering 680-970 nm were obtained and averaged to produce a reference spectrum for the healthy artery wall. The reference spectrum was normalized and compared to all normalized spectrums in the in vivo PA images. The arterial wall was then automatically identified using a cost function and thresholding. To decrease noise in the resulting spectrums, the PA images were first corrected for motion artefacts using phase-based motion tracking on the ultrasound images.

Results, Discussion and Conclusions
The results obtained in images (will be shown) demonstrate that tissue specific spectrums obtained ex vivo combined with this method can be very useful to automatically identify small sections of specific tissue in vivo. Manual delineation to identify tissue specific spectrums in vivo is both time consuming and suffers from motion artefacts and noise due to interference from other tissue. The novel method has potential to facilitate future non-invasive diagnosis of GCA as well as other clinical applications of PAI.