Augmented-Reality-based Needle Interventions with Hololens

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Introduction

Ultrasound-guided needle interventions can be complicated. Seeing the ultrasound image only on the screen of the ultrasound device compels physicians to merge the virtual ultrasound image and the real patient's anatomy in mind. The target of the biopsy and the inserted needle can only be seen when they are directly beneath the transducer. Physicians often have to switch between so-called „in plane" and „out of plane" technique to hit the target accurately.
A software ("ARNI" - Augmented Reality Needle Intervention) was developed as an alignment tool using augmented reality (AR).

Methods

The ARNI-hardware was attached to an ultrasound device (Alpinion E-CUBE i7) to collect the ultrasound images via the DVI-port of the E-CUBE i7 in real-time. The images were sent wireless to a pair of AR-glasses (Microsoft Hololens). "Optical markers" were attached to the transducer and the needle. The ARNI-software detects both markers using the Hololens' integrated camera. Physicians can see a) a virtual ultrasound image beneath the transducer, b) a virtual presentation of the needle superimposed on the real needle, and c) a target marking where the intersection of needle axis and ultrasound image, i.e. the point where the needle hits the ultrasound image when it is moved forward.
The ARNI-prototype was tested by different users (three ultrasound beginners, one expert). The users had to hit a target (mass of approximately 10 mm in diameter) inside an ultrasound phantom at a depth of approximately 20 mm.

Results

The ARNI-prototype can show the AR-content in the Hololens with a delay of <0.2 seconds, which was acceptable for all users. Users had not to switch between „in plane" and „out of plane" technique, what made the biopsy more ergonomic. Every user was able to hit the target at first try.

Conclusion

AR-systems like ARNI can be helpful during needle interventions. Further tests and studies had to be carried out to evaluate the precision of the system and to optimize the human-system interface.

A new filter system for endoscopic fluorescence detection of Protoporphyrin IX and its direct precursors in PDT

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Introduction

Photodynamic therapy (PDT) is a potential option for treatment of cancer since it can be performed non- invasive for superficial cancers or minimal-invasive with low traumatization. But PDT is intrinsically inefficient due to the complex accumulation of the photosensitizing drug inside the tumor and the processes of heme syntheses to create the needed cell killing components. To optimize the outcome of PDT and increase acceptance as viable option it is necessary to predict the optimal time for the start of the treatment based on measurable precursors. A former cell study proposed a new filter fluorometer in a complex and sensitive setup. In this work we now designed and tested a simplified system that can be used in combination with standard endoscopic imaging systems. This system will be used as base to prove viability of this approach for a future clinical study.

Methods

To develop an efficient concept, we observed urologists using a Photodynamic diagnostic (PDD) system for transurethral bladder resection. Based on the findings a filter box with standard endoscopic eypieces was designed and manufactured by 3D printing. This box contains a bandpath filter of 620nm to detect emission of the precursors coroporphyrin III (CPIII) and uroporphyrin III (UPII) and a second 630nm filter to observe the production of protoporphyrin IX (PPIX) that is needed for the cell killing effect of PDT. The filterbox can be placed between camera and endoscope under a sterile cover.

Results

The functionality of the filterbox was tested on liquid samples of CPIII and PPIX. As expected using the 620nm filter intensity was higher in CPIII and using the 630nm filter intensity was higher in PPIX.

Conclusion

A new filter system for endoscopic systems to differentiate PPIX and CPIII fluorescence was built and tested. We could confirm the general functionality in laboratory tests.

Development of in-vitro Vessel Phantom for Computer-assisted MRI-guided Thrombectomy and Vena Cava Filter Implantation

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Introduction

Blood clots formed in deep veins compromise blood flow and migrate as thromboembolisms, creating infarcts or life-threatening pulmonary embolisms. Catheter-guided thrombectomy is usually performed using X-ray fluoroscopy, involving ionizing radiation, nephrotoxic contrast agents, and yields poor soft tissue contrast. Magnetic resonance imaging (MRI)-guided thrombectomy would overcome these drawbacks and benefit from fast imaging and arbitrary slice orientation. This project aimed to develop an anatomically-correct, MR-safe venous vessel phantom and real blood clots. The phantom should allow realistic in-vitro testing of devices for thrombectomies and implantation of Vena Cava Filters (VCFs) using an interventional MRI setup.

Methods

Phantom built process: Anonymised medical imaging (computed tomography and MRT) data is segmented using a region growing method to create a 3D computer model of a human venous vessel system. A corrodible core of the 3D vessel model is manufactured using additive manufacturing according to the image data. Subsequently a silicone-based vessel phantom is produced in a hybrid negative casting process. A Chandler-loop system for the production of bioartifical bloodclots is manufactured using 3D printing technology (Fused Depsition Modelling, FDM). The system consists of a motor-driven rotating silicone tubing system in a warm water bath.

Results

It was possible to manufacture a silicone-based phantom simulating a peripheral vessel system. The phantom is mounted inside a plexiglass tank, which allows the addition of body tissue mimicking water-binging gels like gelatine. This system together with bioartificial blood clots allows the simulation of VCF implant- and explantations, as well as thrombectomies inside a clinical MRI.

Conclusion

Our newly developed phantom in-vitro setup allows simulated implantations of VCFs under MRI guidance for the evaluation of novel medical instruments and interventional setups. In further course of the project physiological blood flow will be simulated by eithter elevateted reservoirs (gravity), electric or pneumatic pumps connected to the vessel-system.

Acquisition of Clinical Workflow of EMB for Development of Computer-assisted MRI-guided Interventions

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Introduction

Minimally invasive procedures like endomyocardial biopsy (EMB) are currently performed under X-ray guidance. Insufficient soft-tissue contrast, ionizing radiation, and nephrotoxic contrast agents are intrinsic drawbacks. Modern wide bore MR scanners, powerful hard-, and software enable the translation into the MRI environment. Feasibility studies have been carried out addressing the visualization/tracking of conditional instruments, and communication/control systems. Main goal of this work is to combine and improve these advances and provide an optimized workflow to bring MRI-guided interventions one step closer to daily clinical routine and overcome disadvantages of X-ray-based imaging.

Methods

Besides development of MR Safe/Conditional instruments, conventional workflow was analyzed utilizing literature and expert interviews. Nine EMB procedures were observed at Department of Cardiology, University Hospital, Leipzig University. Here, actions, durations, instruments, medical devices, affected anatomical structures, given medication, and imaging requirements were acquired systematically. The Business and Process Modeling Notation (BPMN) was used to structure the collected information for visualization and further computer assistance of working steps.

Results

A general application of the EMB routine leads to following subdivision: (1) patient preparation, (2) OR preparation, (3) intervention, (4) follow-up, (5) cleaning & documentation. Except for (3), durations of working steps did not scatter significantly during procedures with X-ray guidance. Main reason for long intervention times was the number of biopsies (extraction of tissue samples) deducted from the patient. The clinician required up to 15 trials (each taking around 1 min) to get the demanded five samples with sufficient size for pathological investigations.

Conclusion

Analysis of EMB workflows under X-ray guidance has shown potential for several improvements and served as framework for novel developed MRI-guided interventions. Due to arbitrary slice selection during MR imaging with improved illustration of ventricular views, and use of flexible, steerable instruments, the number of failed biopsy attempts could be minimized. Comparative in-vitro investigations of sub-processes in MR environment have to be conducted to guarantee feasibility and safety of MRI-guided interventions. Also, support systems like remote MR scanner control, communication setup, and mobile devices need to be installed to further optimize the procedure.

Test of a thin ureteroscope for imaging of intravascular procedures

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Introduction

Endoscopic imaging is used in several medical disciplines for diagnostic and treatment observation. It is intuitive, since information presentation is close to natural human cognition. Endoscopy is rarely used in intra vascular procedures (angioscopy) even though there are clear benefits for diagnostic. Angioscopy allows, for example, the assessment of plaques, vessel wall dissections or implants. But a suitable endoscope is needed. We show a feasibility test of a thin standard ureteroscope with integrated working channel for observation of placement of vascular implants. The integrated bending function of the endoscope is used to support access into bifurcations under direct optical image guidance.

Methods

To test the approach of optical image guided intravascular procedures we first created an artificial test sample out of silicone rubber. A conventional endoscopy system combined with a thin ureteroscope was used for image acquisition. For the tests, standard vascular devices made for coronary or neurovascular procedures were used. Four different tests were conducted under optical image guidance: side branch access, stenting, aneurysm access and coiling. The procedure times were recorded.

Results

Feasibility and potential of optical image guided intravascular procedures could be shown. All tested maneuvers could be realized successfully in a short time. The endoscope is small enough to be utilized in several vascular procedures. The image quality of the system used is high but images will be blurrier in reality due to mixture of the flushing liquid with blood particles. The observation of the vascular procedures is intuitive due to the presentation close to natural human cognition. This also has the potential to speeds up the maneuver times.

Conclusion

Even though angiography adds more complexity to vascular procedures it offers superior visual feedback to perform interventions. Additionally, due to the intuitive presentation of the scene it has the potential to reduce procedure and radiation time.

Non-invasive, passive acoustic sensing – potential applications in arthroscopic surgery

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Arthroscopic surgery is a technically challenging but common minimally invasive procedure with a long learning curve and a high incidence of iatrogenic damage. These damages can occur due to the lack of feedback and supplementary information regarding tissue-instrument-contact during surgery. Deliberately performed interactions can be used however to obtain clinically relevant information, e.g. when a surgeon uses the tactile feedback to assess the condition of articular cartilage. Yet, the perception of such events is highly subjective. We propose a novel non-invasive sensing concept applied to arthroscopic surgery to allow an objective characterization and utilization of interactions. It is based on acoustic emissions which originate from tissue-instrument-contact, that propagate naturally via the instrument shaft and that can be obtained by a transducer setup outside of the body. The setup was tested on its ability to differentiate various conditions of articular cartilage. A femoral head with varying grades of osteoarthritic cartilage was tapped multiple times ex-vivo with a conventional Veress needle equipped with a sound transducer. A wavelet-based processing of the obtained signals and subsequent analysis of distribution of spectral energy showed the potential of tool-tissue-interactions to characterize different cartilage conditions. The proposed concept needs further evaluation with a dedicated design of the palpation tool and should be tested in realistic arthroscopic scenarios.

Submission of Abstracts for Oral or Poster Presentation

Cochlear monitoring during and after CI-Insertion using intracochlearly recorded Electrocochleography

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Introduction

To preserve residual hearing during CI insertion it is desirable to use intraoperative monitoring of the cochlea. A promising approach is the recording of cochlear microphonics using Electrocochleography (ECochG).

Methods

During the insertion of hearing preservation CI electrodes the potentials were recorded using the CI electrode at contact one. After insertion the recording was done at different electrode contacts. The stimulation was done acoustically using 500 Hz tone bursts. For recording the clinical CI software (Maestro, Medel) was used. After 6 months the recording at different contacts was repeated. The location of the electrode in the cochlea during insertion was estimated using preoperative radio imaging (CT scan) and mathematical modelling, the postoperative location was measured using postoperative radio imaging (cone beam CT scan). Up to now 6 patients were included.

Results

In most of the cases the signal amplitude rose during the insertion. In patients with good residual hearing the largest amplitudes were recorded at electrode contacts which lay closest to the generators of the stimulation frequency.

Conclusion

The intracochlear ECochG during and after CI insertion is very good possible and seems to yield consistent results to the location of the electrode in the cochlea.