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BLOOD VESSEL STENOSIS QUANTIFICATION IN CT AND MR DATASETS BY VIRTUAL ELASTIC SPHERE FITTING

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Purpose: To implement a tool for objective quantification of blood vessel stenosis in CT, dual energy CT (DECT) and MR angiography data sets and to evaluate improvements of accuracy and reproducibility compared to manual caliper measurements.

Method and Materials: Our newly developed tool requires start and end points of a blood vessel of interest, based on which the vessel lumen is segmented, through which a virtual elastic sphere is fitted subsequently. The locally adjusting diameter of this elastic sphere along the vessel course is tracked and minimal and reference diameters are determined to compute a stenosis score according to the commonly used NASCET criteria. After verifying the accuracy of the tool with vessel phantoms, it was applied to measure diameters of carotid arteries in µCT data set of ApoE -/- mice that had undergone partial ligation of the left carotid artery. All experiments were approved by the animal care institutions. Furthermore, the tool was applied to measure stenosis scores in review board-approved prospectively acquired contrast enhanced dual energy CT (DECT) and MR angiography data sets of carotid artery stenosis patients. Consistency with manual stenosis scoring was evaluated and reproducibility of semi-automated and manual scoring was compared. A novel method of automated DECT-based discrimination between iodine-enhanced blood and calcifications was implemented and compared to a method for standard CT.

Results: Diameters of vessel phantoms were correctly determined with sub-pixel precision using the semi-automated tool. For µCT angiographies of ApoE -/- mice, our tool revealed significant differences between diameters of normal and injured carotid arteries ($P<0.01$). For MR and CT patient data sets, time-efficiency (36 vs. 104 seconds per carotid artery) and reproducibility ($P<0.01$) were significantly improved compared to manual measurements. Automated and manual stenosis scores correlated strongly ($P<0.001$), showing the consistency of the method with manual measurements. DECT-based tissue discrimination did not generate significantly different scores due to the small number of patients.

Conclusion: Our virtual elastic sphere tool is widely applicable, efficient to use and improves reproducibility over manual stenosis scoring.

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INTERACTIVE SYSTEM FOR EXPLORATION OF MULTI-MODAL RAT BRAIN DATA

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Introduction: In pre-clinical research, the combination of structural (MRI, CT, ultrasound), functional (PET, SPECT, specialized MRI protocols) and optical (BLI, FLI) imaging modalities enables longitudinal and cross-sectional studies in living organisms. The goal of this work is to develop software for interactive exploration of heterogeneous multi-modal data in follow-up studies.

Methods: To enable comparison and integration of follow-up multimodal data, image registration is required, where we differentiate inter-modal registration and intra-modal registration to detect changes over time. To combine different modalities rigid registration is used to compensate for any rotation or translation that exists between different datasets. To detect the changes in different regions of the brain over the life-cycle (deformation, tumor growth, etc.), the different time-points are elastically/non-rigidly registered to each other. For each elastic registration, the deformation field and the correspondent determinant of the Jacobian (detJac) are calculated. When comparing 2 different time-points the information provided by the deformation field can be used: without distorting the original data one can automatically pin-point the exact same region/voxel in both datasets and understand what deformation the brain suffered from one time-point to another in all directions. Analyzing the detJac one can find whether a specific region of the brain suffered any local compression or expansion.With the registration results for any possible combination of data at hand, one can easily choose what to visualize and compare side by side: same subject-same modality-different time-points, different subjects-same modality-same time-points, same subject-different modalities-different time-points, different subjects-different modalities-same time-point, etc. In the proposed method the registration was performed using elastiX© [1] and the visualization interface was built using MeVisLab™.

Results: The proposed approach was first tested using multi-modal follow-up data of 1 male Wistar rat (Harlan-Winkelmann). It was scanned repeatedly (every 2 months from 10 to 20 months of age) under 2% isoflurane anesthesia using a horizontal bore 11.7T Bruker BioSpec MRI scanner. Diffusion tensor imaging was used to calculate fractional anisotropy, mean diffusivity and eigenvalue maps; a multislice multiecho experiment was performed to calculate T2 maps; both datasets were acquired with identical geometry and spatial resolution. T2*maps were acquired with a multi gradient echo sequence, angiography scans with a FLASH-2D TOF sequence with or without saturation of venous blood. It was used to identify and follow in time a spontaneous brain tumor growth, later identified *ex vivo* as a melingeom. The automatic linking of the same ROI/voxel in non-rigidly registered datasets and the use of the detJac to search for asymmetries in brain deformation allowed for a more accurate comparison of follow-up data.

Conclusions: In this work we describe the first step taken to build an interactive and intuitive to use exploration system for multi-modal longitudinal and cross-sectional studies. In the future, quantification tools will be added to the platform and an intensive validation will be performed with multi-modal life-span rat brain data.

References: [1].Klein & Staring *et al.,* 'elastix: a toolbox for intensity based medical image registration,' IEEE-TMI, 2010