MSc Projects Dept. of Radiology, MUMC+

Research in Medical Imaging is a key topic of the Maastricht University Medical Center (MUMC+). Especially, neuroimaging is an important and intensively developing field of research in Maastricht. This is not only to improve the diagnosis and therapeutic evaluation of diseases of the central nervous system, but also to advance our understanding of the physiopathology for finding novel points of therapy or prevention. For this, we closely collaborate with medical professionals from various medical departments including Neurology, Neuropsychology, Neurosurgery and Internal Medicine, and scientists from the Research School for Mental Health & Neuroscience.

Magnetic Resonance Imaging (MRI) is often the preferred choice of imaging the central nervous system. The Radiology & Nuclear Medicine department offers access to state-of-the-art medical imaging systems, including a variety of MRI systems with various field strengths ranging from 1.5, 3.0, 7.0 to 9.4 Tesla and also PET-MRI relevant for brain imaging. In addition, we facilitate large computer cluster systems for complex computational image analyses and physiologic modeling. Our mission is to develop and evaluate novel medical imaging techniques for diseases in a clinical setting.

As novel developments in medical imaging are strongly dependent on input from various disciplines, including medicine, psychology, medical physics, and especially engineering, we welcome interested technical university students to help us with this challenging task. At the Radiology department of Maastricht UMC+ we invite (Master) students with a technical/engineering background in Physics, (Bio-) Medical or Electrical Engineering to perform their research graduation projects. For this we have employed a number of highly educated principle investigators as well as PhD students that can inform and supervise your project.

In case you are interested in a project and feel capable to bridge the disciplines of medicine and engineering please contact us to become acquainted or contact one of the researchers linked to the specific projects described in the following pages.

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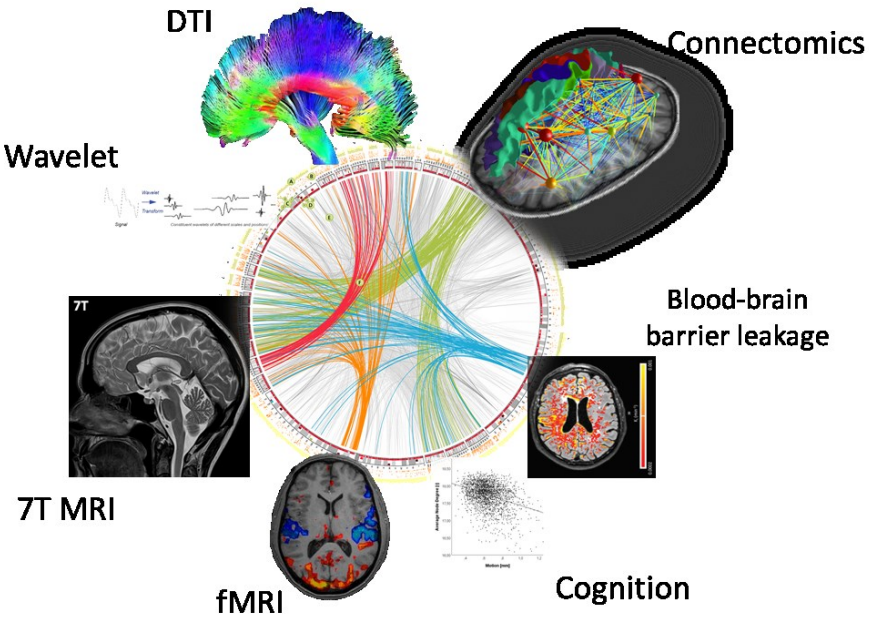
Department of Radiology & Nuclear Medicine

Maastricht UMC+

LIST OF RESEARCH PROJECTS

- Analysis of longitudinal MRI data in children with childhood absence epilepsy
- Non-invasive determination of the intracranial pressure using CT images in patients with a traumatic brain injury
- Determining the correlation of the resting-state functional MRI signal with cognition or blood pressure using wavelet analysis in The Maastricht Study
- Blood-brain barrier leakage measured with dynamic contrast-enhanced MRI
- Structural connectivity of the hippocampal subfields measured using diffusion tensor MRI at 7T
- Measuring cerebral blood flow pulsatility in hypertensive patients using 7T MRI



ANALYSIS OF LONGITUDINAL MRI DATA IN CHILDREN WITH CHILDHOOD ABSENCE EPILEPSY

BACKGROUND

Childhood absence epilepsy (CAE) is one of the most prominent types of epilepsy in children. CAE is characterized by daily occurring brief losses of consciousness in otherwise normally developing children. However, recent studies have shown a higher incidence of academic difficulties and cognitive deficits (mainly attentional deficits) in CAE. Furthermore, abnormal structural connectivity was previously reported in children with CAE using diffusion weighted imaging. However, how these abnormalities change over time is not yet completely understood.

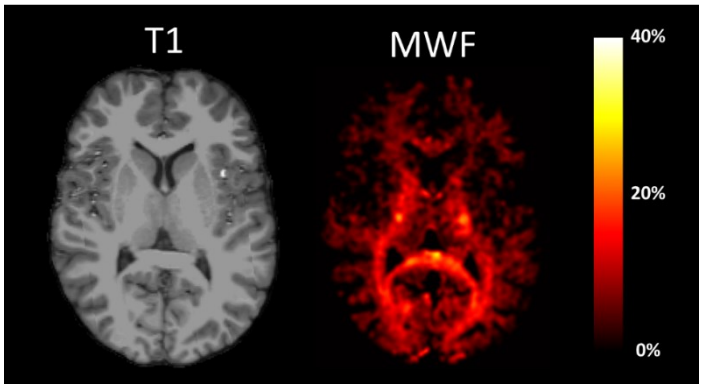


Fig. 1 Baseline T1 weighted image and myelin-water fraction map for a 10-year-old boy with childhood absence epilepsy.

A study was designed to investigate the impact of CAE on neurocognitive performance and brain development on a longitudinal basis. For this, children with CAE are followed for 2 years including three MRI sessions (baseline, after one year and after two years). Functional as well as structural MRI data are acquired. For example, baseline results of the study have already revealed that children with CAE have a lower frontal myelin content (= a fatty substance wrapped around the axons that accelerates the electoral signals along the axon) **(Fig 1.)**. However, from the baseline data alone it is unclear if this is a cause or an effect of CAE. Further analysis using the longitudinal data could provide insights in the underlying mechanisms of CAE.

PROJECT GOAL

The student is challenged to investigate the structural and/or functional brain organization over time.

STUDENT PROFILE

- Experience with Matlab is required

CONTACT

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NON-INVASIVE DETERMINATION OF THE INTRACRANIAL PRESSURE USING CT IMAGES IN PATIENTS WITH A TRAUMATIC BRAIN INJURY

BACKGROUND

Traumatic brain injury (TBI) is a major cause of long-term disability in industrialized and developing countries across the world. TBI can cause swelling of the brain tissue leading to uncontrolled raised intracranial pressure (ICP). This is dangerous for the TBI patient, as it can result in severe brain damage or even death. Currently, ICP monitoring is performed using a parenchymal catheter. The placing of the catheter is an invasive procedure which may cause complications. Therefore, a non-invasive technique to measure and monitor ICP would be beneficial for TBI patients.

Standard routine for TBI patients in the hospital includes the performance of a computed tomography (CT) scan. A high ICP results in a decrease of cerebrospinal fluid (CSF) due to parenchymal swelling, and an increase in the optic nerve sheath diameter (ONSD). Therefore, CT scans may also be used as a suitable technique for non-invasive ICP monitoring, for example by assessing the ratio of CSF the versus the intracranial volume (ICV) (**Fig. 1**), or by measuring the ONSD (**Fig. 2**). These measures are relevant for future ICP monitoring of TBI patients.

The project is a collaborative effort with Dr Marcel Aries from the Department of Intensive Care, who maintains a rich dataset of ca. 25 TBI patients.

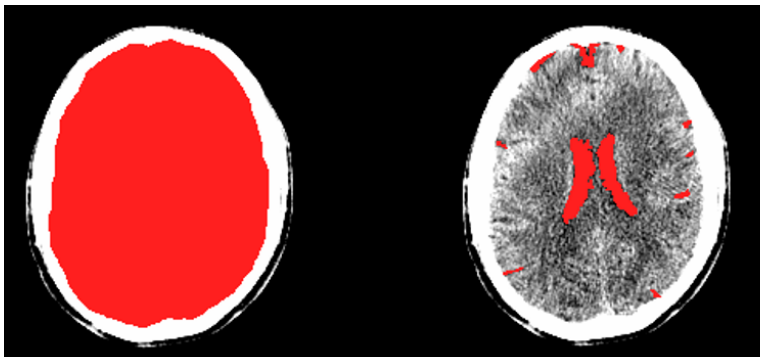

Fig. 1 Automatic segmentation of ICV (left) and CSF (right) volumes on a transverse CT slice.

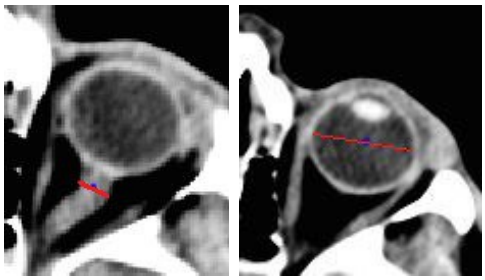

Fig. 2 Measurement of the ONSD (left), and the eyeball transverse diameter (right).

PROJECT GOAL

To program and implement automated procedures for the assessment of CSF/ICV volumes and ONSD in CT images from TBI patients.

STUDENT PROFILE

- Experience with Matlab is required

CONTACT

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DETERMINING THE CORRELATION OF THE RESTING-STATE FUNCTIONAL MRI SIGNAL WITH COGNITION OR BLOOD PRESSURE USING WAVELET ANALYSIS IN THE MAASTRICHT STUDY

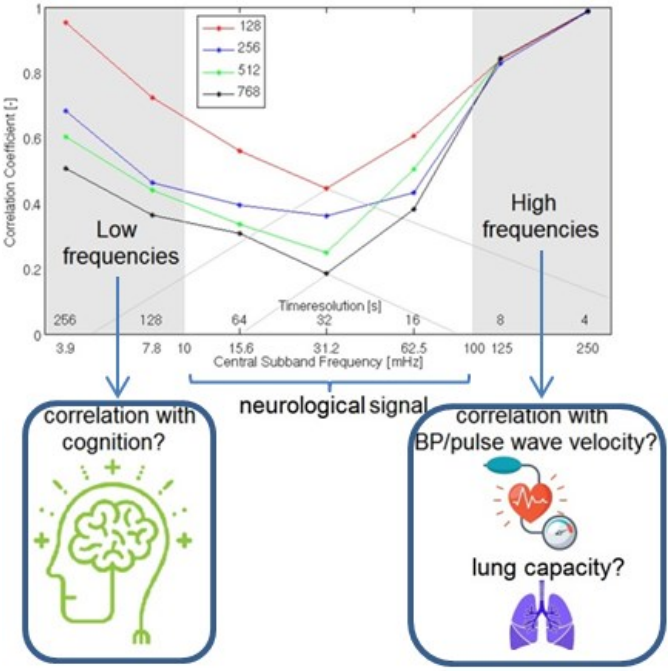
BACKGROUND

Wavelet Analysis:

Neuronal signals are non-stationary, therefore the standard Fourier analysis is not adequate enough because it loses all information about the time localization of the frequency components.

The Wavelet Transform is well localized in both time and frequency domain and is therefore a promising method to analyze resting-state functional MRI scans.

Wavelet correlations can be used to investigate which brain regions operate at which timescales.



The Maastricht Study:

PROJECT GOAL

Determining the correlation of the resting-state functional MRI signal with cognition or blood pressure using wavelet analysis in the Maastricht Study.

CONTACT

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BLOOD-BRAIN BARRIER LEAKAGE MEASURED WITH DYNAMIC CONTRAST-ENHANCED MRI

BACKGROUND

The blood-brain barrier (BBB) separates circulating blood from the brain parenchyma. It delivers important nutrients to the brain, prevents neurotoxins from entering and removes waste products. A well-functioning BBB is essential to keeping brain tissue in a healthy condition. Deterioration of the BBB may play an important role in the onset of brain-related diseases, e.g. Alzheimer disease.

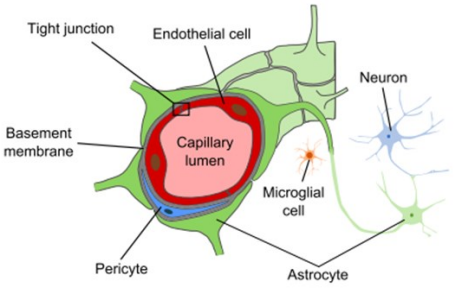

Fig. 1 The blood-brain barrier consists of a series of high-resistance, tight junctions between endothelial cells as well as astrocytic end-feet that overlap the capillary wall.

A promising method to assess the permeability of the BBB is dynamic contrast-enhanced magnetic resonance imaging (DCE-MRI). Whereas DCE-MRI has originally been developed to detect the high leakage observed in (non-brain) tumours, the DCE-MRI technique has been improved to also detect subtle BBB leakage[1].

The currently used method uses a dual temporal resolution DCE-MRI protocol consisting of a high temporal/low spatial resolution part, which is applied around time of contrast administration to capture the initial phase of contrast enhancement (first 90 seconds), followed by a low temporal/high spatial resolution part to capture long-term (30 minutes) contrast enhancement. After pre-processing the acquired MRI data, the voxelwise leakage rate is calculated using the Patlak graphical approach, resulting in leakage maps (**Fig. 2**).

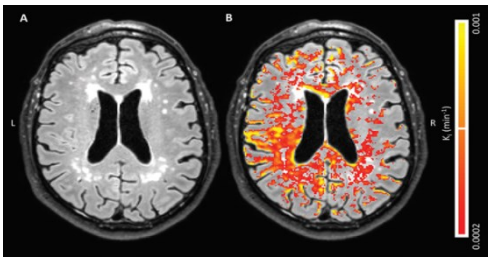

Fig. 2 Axial fluid-attenuated inverse recovery image (FLAIR) (left) with leakage map superimposed (right).

[1] van de Haar et al. Blood-Brain Barrier Leakage in Patients with Early Alzheimer Disease. *Radiology*. 2016;281:527-535

PROJECT GOAL

Although results are encouraging, the currently used method still can be improved. Among others, the following questions need to be addressed:

- How to deal with scanner drift?
- Is the Patlak graphical approach suitable to measure permeability of the circumventricular organs?
- To what extend are the leakage values affected by the input function (location and timing)?

STUDENT PROFILE

- Experience with Matlab and willing to work with commonly used neuroimaging software
- Preference for working with in-vivo MRI data in a clinical environment

CONTACT

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STRUCTURAL CONNECTIVITY OF THE HIPPOCAMPAL SUBFIELDS MEASURED USING DIFFUSION TENSOR MRI AT 7T

BACKGROUND

Traditionally, the hippocampus is considered as a single brain formation. However, it has been suggested that the hippocampus is a heterogeneous structure, which can be divided into hippocampal subfields with different cellular components and molecular mechanisms. Previous studies have suggested that specialization of these subfields occurs. Increasing evidence has also suggested that hippocampal subfields are differentially affected by diseases, such as epilepsy. Therefore, an increase in understanding of their structure can help in a better understanding of epilepsy.

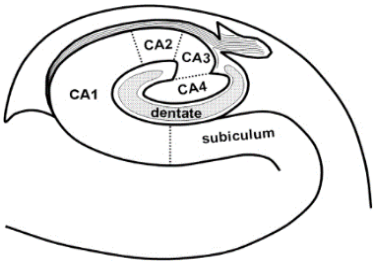

Fig. 1 Division of the hippocampus into the hippocampal subfields

Non-invasive imaging is a promising method to assess structural connectivity of the hippocampal subfields and although non-invasive assessment of the subfield organization using conventional clinical MRI scanners remains challenging, development of ultra-high field strength (i.e. 7 T) scanners increases the possibilities to obtain images with an increased spatial resolution and increased contrast, without compromising data quality and increasing scanning time. These improvements make it possible to accurately assess the structural connectivity of the hippocampal subfields using diffusion tensor imaging (DTI).

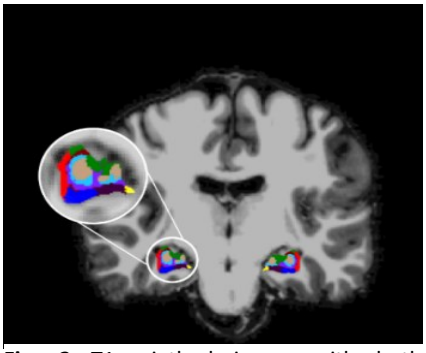

Fig. 2 T1-weigthed image with both segmented hippocampal subfields superimposed.

PROJECT GOAL

Structural and diffusion weighted images are already acquired for a small group of healthy controls and epilepsy patients. The following questions need to be addressed:

- How to deal with DTI preprocessing?
- Is it possible to assess the structural connectivity of the hippocampal subfields?
- Are there differences in structural connectivity between healthy controls and epilepsy patients?

STUDENT PROFILE

- Experience with Matlab and willing to work with commonly used neuroimaging software
- Preference for working with in-vivo MRI data in a clinical environment

CONTACT

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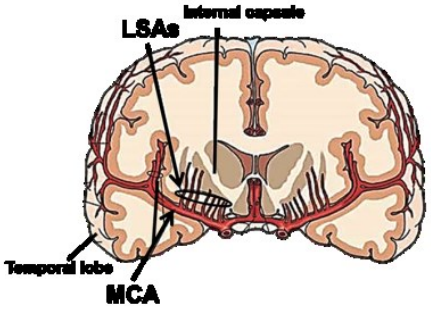
MEASURING CEREBRAL BLOOD FLOW PULSATILITY IN HYPERTENSIVE PATIENTS USING 7T MRI

BACKGROUND

Hypertension is a highly prevalent condition, which is a leading cause of morbidity and mortality. Hypertension causes damage in the structure and function of the vasculature in general and in several end organs, such as kidneys, heart and brain. Furthermore, it is strongly related to cerebral small vessel disease and is a major risk factor for cognitive deficits and dementia.

However, the precise pathophysiology for the brain damage resulting from hypertension is still unclear, although microvascular dysfunction is thought to play an important role. It is suggested that the blood flow pulse is less dampened due to stiffer vessels, which results in an increased energy transmitted to the brain tissue.

The small intracranial vessels (LSA) provide blood to deep brain structures, the same structures where tissue damage is found in cerebral small vessel disease patients. These small cerebral vessels can be visualised using high resolution imaging with 7T. Moreover, using phase contrast MRI the blood flow velocity in these vessels can be measured. Combining this technique with structural MRI, allows to study the suggested relation between the characteristics of the blood flow velocity and the brain tissue damage in hypertension.



PROJECT GOAL

The blood flow measurements in the small intracranial vessels are currently being optimized. Possible projects could be:

- Comparing flow measurements in the LSA in 1 direction versus 3 directions
- Automatic thresholding for velocity analysis
- Comparing different methods of calculating the vessel area

STUDENT PROFILE

- Experience with Matlab and willing to work with commonly used neuroimaging software
- Preference for working with in-vivo MRI data in a clinical environment

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