

Göteborg, 2018

Intravoxel incoherent motion modeling

Optimization of acquisition, analysis and tumor tissue characterization

AKADEMISK AVHANDLING

som för avläggande av medicine doktorexamen vid Sahlgrenska akademien, Göteborgs universitet kommer att offentligens försvaras i Hörsal Arvid Carlsson, Academicum, Medicinargatan 3, fredagen den 5 oktober, klockan 9.00
av

Oscar Jalnefjord

Fakultetsopponent:
Professor Ronnie Wirestam
Lunds universitet, Lund

Avhandlingen baseras på följande delarbeten:

- I. **Impact of prior distributions and central tendency measures on Bayesian intravoxel incoherent motion model fitting**
Oscar Gustafsson, Mikael Montelius, Göran Starck, Maria Ljungberg
Magnetic Resonance in Medicine 2018;79(3):1674-1683
- II. **Comparison of methods for estimation of the intravoxel incoherent motion (IVIM) diffusion coefficient (D) and perfusion fraction (f)**
Oscar Jalnefjord, Mats Andersson, Mikael Montelius, Göran Starck, Anna-Karin Elf, Viktor Johanson, Johanna Svensson, Maria Ljungberg
Magnetic Resonance Materials in Physics, Biology and Medicine 2018; *In press*
- III. **Optimization of b-value schemes for estimation of the diffusion coefficient (D) and the perfusion fraction (f) with segmented intravoxel incoherent motion (IVIM) model fitting**
Oscar Jalnefjord, Mikael Montelius, Göran Starck, Maria Ljungberg
Manuscript
- IV. **Data-driven identification of tumor subregions using intravoxel incoherent motion**
Oscar Jalnefjord, Mikael Montelius, Jonathan Arvidsson, Eva Forssell-Aronsson, Göran Starck, Maria Ljungberg
Manuscript



UNIVERSITY OF GOTHENBURG

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ABSTRACT

Intravoxel incoherent motion (IVIM) analysis provides a means to obtain information on diffusion and perfusion from a single MRI sequence. The measurements are completely noninvasive and the results have been shown to be of interest for example in oncological applications. Although the use of IVIM analysis has increased substantially the last decade, choice of acquisition parameters and analysis methods are still open questions.

The aim of this thesis was to improve IVIM analysis by optimization of the image acquisition and parameter estimation methods, and to study the ability of IVIM parameters to be used for tumor tissue characterization.

With standard model-fitting methods and data quality, IVIM parameter estimation uncertainty is typically high. However, several Bayesian approaches have been shown to improve parameter quality. In Paper I, these Bayesian approaches are compared using simulated data and data from a tumor mouse model. The results emphasize the impact of methodological choices, especially the prior distribution, at typical noise levels.

Quick and robust IVIM examinations are important for clinical adoption, but consensus regarding methodology is lacking. To address this issue a framework for protocol optimization is presented in Paper III and a comparison of estimation methods was done in Paper II. To test the optimization framework, a protocol for liver examination was generated and tested on simulated data and data from healthy volunteers resulting in improved IVIM parameter quality. The compared estimation methods were evaluated on simulated data and data from patients with liver metastases with similar results for all methods, thereby making the computationally most effective method preferable.

Studies of tumors using quantitative imaging methods such as IVIM often only extract an average parameter value from the entire tumor and may thus miss important information. Paper IV explores the ability of IVIM parameters to identify tumor subregions of functionally different status using clustering methods. The obtained subregions were found to have different proliferative status as derived from histological analysis.

The work presented in this thesis has resulted in improved IVIM acquisition and analysis methods. It also shows that IVIM has the potential to provide insight into tumor physiology and be used as a noninvasive imaging biomarker.

Keywords: IVIM, MRI, diffusion, perfusion, cancer

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