Diffusion-weighted (DW) MRI of the abdomen is utilized clinically in the detection, diagnosis, and treatment monitoring of cancer and non-cancer disease. Despite its enormous potential, poor reproducibility and inefficient clinical workflow of DW imaging remain bottlenecks for rapid, high-value DW-MRI of the abdomen. A central challenge is physiological motion, including cardiac and respiratory motions. As the heart and vessels pulsate, they exert compressive tissue motion in the liver and the pancreas. The compressive tissue motion results in phase variations, leading to signal loss in diffusion-weighted images and bias in quantitative measurements. Furthermore, the slower respiratory motion results in mis-registration among repetitions taken in different phases of the respiratory cycle during free-breathing acquisitions.

Inefficient clinical workflow for DW-MRI acquisition remains another technical challenge. Currently, all abdominal DW-MRI scans are prescribed manually by technologists and routinely acquired with respiratory gating. That workflow requires training of technologists and takes a significant portion of the scan time. The resulting prescription can show high inter-operator variation and occasionally insufficient coverage. A fully automated MRI prescription that would cover the whole liver is needed. Besides, although respiratory-triggering DW-MRI acquisition methods can reduce respiration-induced artifacts, these methods lead to poor SNR and unpredictable scan times due to their highly variable effective repetition time, reducing the efficiency of clinical imaging workflows. In contrast, free-breathing methods without triggering enable abdominal DW-MRI with high SNR efficiency and predictable scan times, albeit at the risk of respiration-induced mis-registration. Thus, there is an unmet need for a free-breathing DW-MRI acquisition combined with motion-corrected averaging, to enable high-SNR DW-MRI with predictable scan times and free from motion artifacts.

This thesis describes technical innovations to address the aforementioned needs in order to enable fully automated, motion-robust diffusion-weighted MRI of the abdomen. An automated AI-based method for image prescription of liver MRI was developed and evaluated to standardize liver MRI prescription and improve the clinical workflow. Additionally, the cardiovascular motion artifacts was characterized and corrected in a motion phantom and healthy volunteers for pancreas DW-MRI. Finally, motion-robust, free-breathing DW-MRI in the liver was developed using optimized motion-compensated diffusion gradient waveforms and a motion-corrected averaging algorithm.