**EDITORIAL**

# Clinical MRI Research in Human Brain Mapping

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## Abstract

The core mission of clinical MRI in Human Brain Mapping (HBM) is formed in a cycle of research, education and practice. Learning the effective diagnostic and treatment planning procedures occurs not in the classrooms but through engagement in active research. Clinical MRI research for HBM initiates with strategic and necessary demands of clinicians, e.g. neurologists, neurosurgeons, psychologists, psychiatrists, etc. who need specific clinical MRI acquisition and quantification techniques for better, faster and more accurate diagnostic and follow-up procedures. Neuro-radiologists are responsible for all aspects of a research MRI examination, including assessment of patient's clinical symptoms, assigning the imaging protocol, reviewing the acquired images for their quality and interpretations, and finally, preparing the reports. MR physicists with their unique scientific qualifications and perception of clinical requirements play a critical role in optimization of the existing protocols, establishment of research investigations and development of effective techniques (including pulse sequences, analysis and quantification software, etc.) for clinical application of MRI in HBM, when responsibility of a clinical scientist is minimal when the research methodology development starts while the physicist starts with the maximum responsibility to develop the methodology, and vice versa when the methodology development progresses from early to the end stages closer to the clinical practice.

**Keywords:** Magnetic Resonance Imaging; Clinical Magnetic Resonance Imaging Research; Human Brain Mapping; Magnetic Resonance Imaging Physicist; Neuro-Radiologist; Neuro-Imaging.



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## 1. Introduction

Clinical Magnetic Resonance Imaging (MRI) plays a pivotal role in radiologic and diagnostic imaging in a variety of pathological disorders. It involves integrating the knowledge of imaging marker development with prediction, diagnosis, assessment, and follow-up of the disease state and progression. Clinical MRI is now a widely-accepted diagnostic and research tool due to its capability in providing superb soft-tissue delineation, multi-planar imaging of the tissue of interest, and multiple non-invasive and quantitative biomarkers of the pathology simultaneously in a single imaging session. Combined with other imaging techniques, clinical MRI offers a strong problem-solving diagnostic and research workflow in Human Brain Mapping (HBM).

The core mission of clinical MRI in HBM is summarized in a cycle of research, education and practice. A successful clinical MRI platform in HBM is established by education of the clinicians and practitioners. Learning the effective diagnostic and treatment planning procedures occurs not in the classrooms but through engagement in active research. This integration nurtures the outcome of an HBM center. As new techniques are being developed rapidly in clinical MRI, the clinical scientist or physicist is responsible for exploring novel MRI techniques, analysis and quantification techniques in HBM.

Clinical MRI research for HBM initiates with strategic and necessary demands of clinicians, e.g. neurologists, neurosurgeons, psychologists, psychiatrists, etc. who need specific clinical MRI acquisition and quantification techniques for better, faster and more accurate diagnostic and follow-up procedures. Neuro-radiologists are responsible for all aspects of a research MRI examination, including assessment of patient's clinical symptoms, assigning the imaging protocol, reviewing the acquired images for their quality and interpretations, and finally, preparing the reports. MR physicists with their unique scientific qualifications and perception of clinical requirements play a critical role in optimization of the existing protocols, establishment of research investigations and development of effective techniques (including pulse sequences, analysis and quantification software, etc.) for clinical application of MRI in HBM. Apparently, the MRI technologist must cooperate in patient preparation and positioning, and in arranging the MRI protocol based on the recommendations provided by the physicist and according to the radiologist's request in a suitable setting for most accurate interpretation. Figure 1 and Figure 2 depict a triangle of research composed of three key roles and their interaction strategy in development of a new clinical MRI research study in HBM, respectively. Figure 2 shows that responsibility of a clinical scientist is minimal when the research methodology development starts while the physicist starts with the maximum responsibility to develop the methodology. This situation changes inversely when the methodology development progresses from early to the end stages closer to the clinical practice.

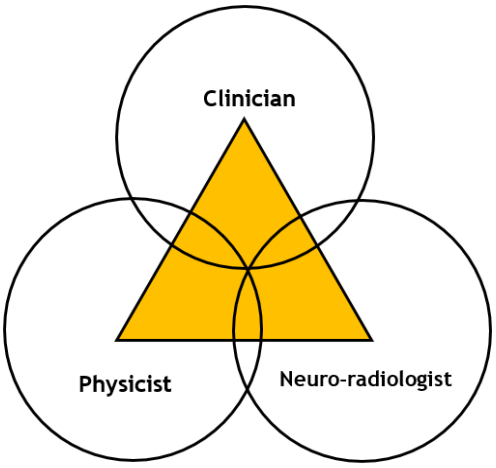


**Figure 1.** The Triangle of Research—Practice Scheme in Human Brain Mapping

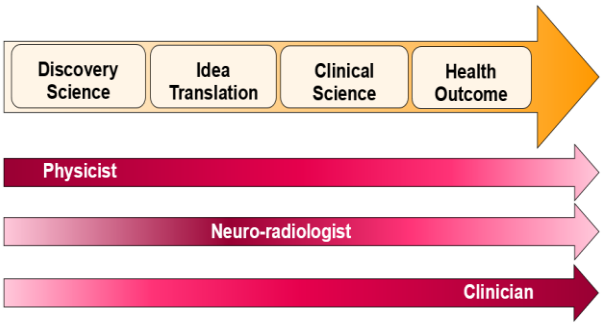


**Figure 2.** The Translational Continuum in Human Brain Mapping

Regarding MRI image acquisition and image analysis for diagnosis and follow-up purposes in HBM, MRI physicist plays a key role in reviewing the image quality, revising the imaging protocols based on the disease, developing the policies for image acquisition and system adjustments, implementing

new quantification techniques based on radiologist's request, and ensuring about reliable implementation of protocols and guidelines. Due to their training in scientific and analytical problem solving, an MRI physicist can greatly influence the HBM research outcome and in development of methodology. According to AAPM report, the following roles must be specified for MRI physicist:

(1) Advancing new HBM diagnostic procedures, based on their expertise in computer systems;

(2) Implementing accurate HBM quantification and analysis techniques;

(3) Optimizing the HBM techniques and clinical applications based on the local clinical demands and available facilities, customizing the pulse sequences, devising new hardware such as surface coils and patient positioning devices.

## 2. Why Quantitative MRI/MRS Matters in Human Brain Mapping?

While we expect medical decision-making to be an evidence-based practice derived from objective scientific data interpretation in HBM, we proclaim that the only certainty in medicine is prevalence of uncertainty [1]. This uncertainty, which is an Achilles heel of the HBM research procedure [2], arises because of a number of factors including technical (improper image quality), insufficient clinical information, anatomical variations, and lack of approved standards [3-4].

The ambiguity of the research outcome in HBM would lead to indecisiveness, lack of confidence of the clinician scientist, and imposing additional diagnostic tests. Nonetheless, the solution to these problems in research methodology development in HBM lies in establishing a decision-making team who build a triangle of single individuals or groups of specialists consisting of referring clinician (and most probably pathologist), radiologist and an MRI physicist (Figure 1). Each vertex of the triangle is committed to share their opinions and responsible for achieving an acceptable diagnosis with quantifiable estimate of uncertainty.

The "engagement" of the collaborative team of specialists in a longstanding and close relationship with each other provides the opportunity to reduce the errors through effective communication and a feedback flow. Thus, the source of uncertainty in clinical MRI research for HBM would be placed and reduced accordingly: if it originates from poor image acquisition strategy, the MRI physicist may advise; if it is relevant to the imprecise clinical MRI data, the referring physician deals with it; or if it corresponds to the subjective error in rendering the images according to the available evidence, the radiologist would take action.

Even a shared decision-making leaves the diagnosis to the art of the radiologist in interpreting the images. However, without having a quantitative estimate, differential diagnosis in HBM research remains unreliable. This highlights the importance of "quantification" in that a quantitative imaging/analysis protocol in HBM methodology development is recommended only when its statistical efficacy is determined and acceptable. According to Paul Tofts [5], "quantification" means "to measure". This single word conveys the whole essence of the "paradigm shift" from relying on subjective opinion towards an impartial objective decision achieved by numeric measures of the scientific phenomena that usually are imperceptible to human vision. In clinical MRI research for HBM, we wish to unveil meaningful quantitative biomarkers of the disease state and progression with descriptive features in terms of sensitivity, specificity, accuracy and reproducibility.

## 3. Team Set-up Principles

In clinical MRI research development and study design for HBM, we believe that the team-based collaborations should follow the principles of the art of developing attachments in a partnership, which could be created by mutual benefits that bounce around six principal ingredients, adopted from "International Society for Magnetic Resonance in Medicine (ISMRM)" [6]: Discover, Connect, Engage, Develop, Save and Access.

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