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Time-dependent diffusion magnetic resonance imaging: measurement, modeling, and applications

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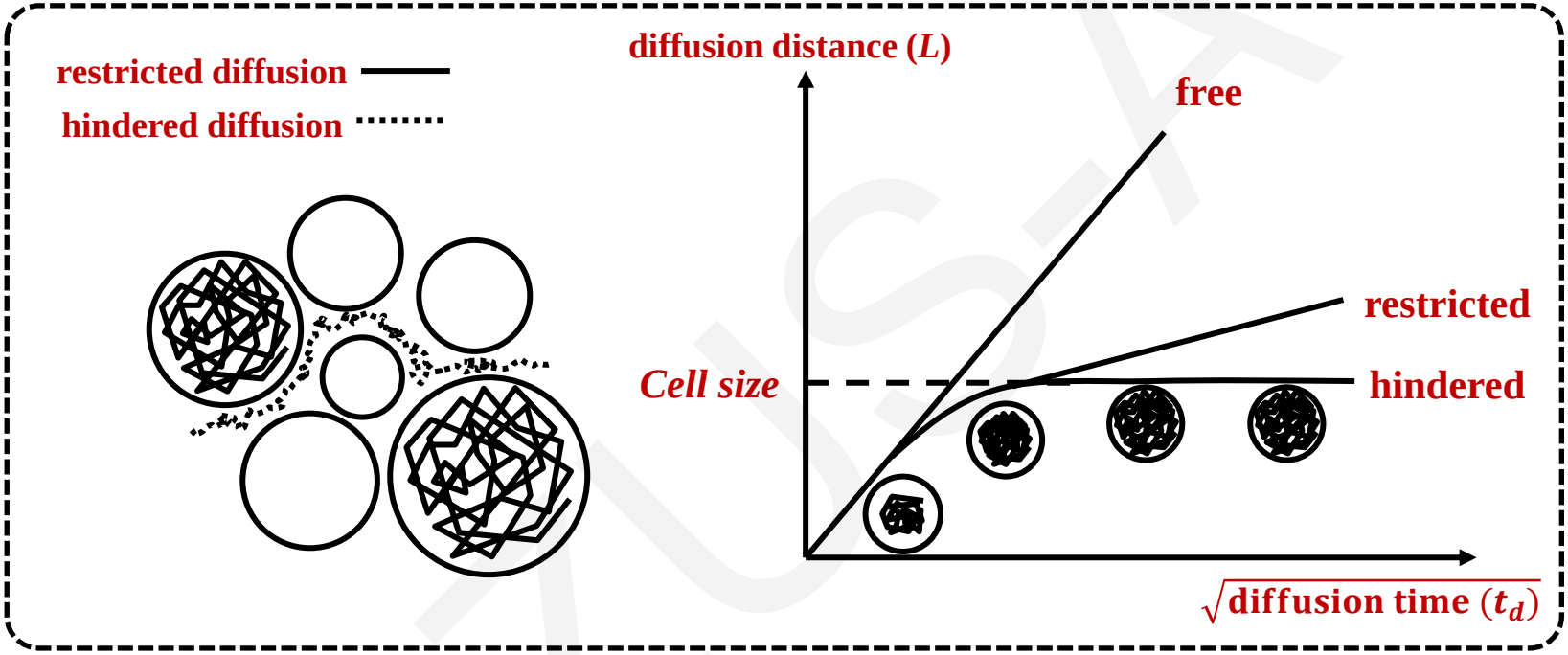
CONCEPT OF TDDMRI

- **Time-dependent diffusion magnetic resonance imaging** (**TDDMRI**), a method that reveals time-related changes in the diffusional behavior of water molecules in biological tissues.



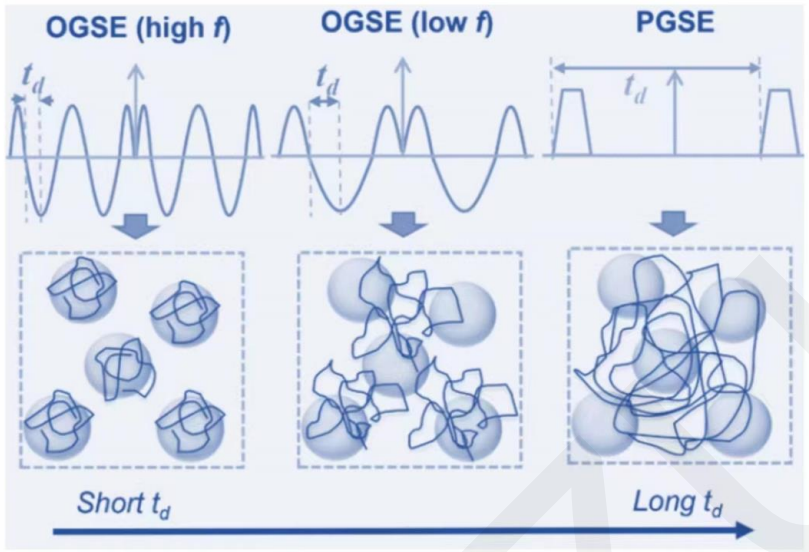
short t_d → Limited diffusion distance, the molecules behave like free diffusion or are hindered within a compartment. → restriction effect

intermediate t_d → mixture effect

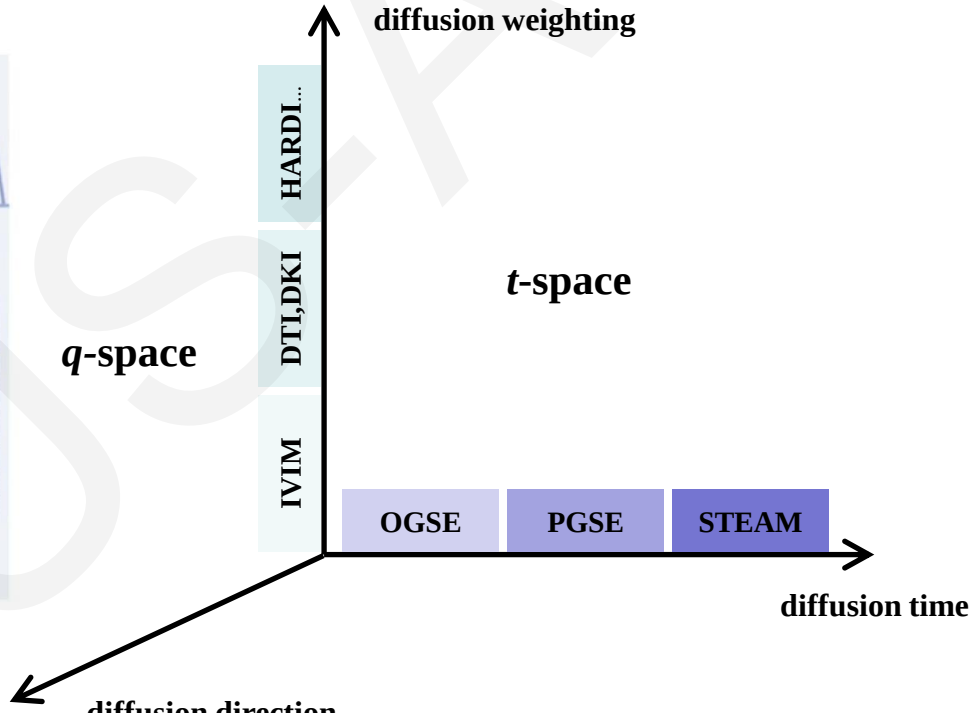
long t_d → Increasing diffusion distance, the molecules moved by exchange from the initial compartment to another. → exchange effect

MEASUREMENT OF TDDMRI

- **Different sequences** were developed to capture the **diffusion characteristics of microstructures** in the **short-** and **long-time regimes** (e.g., **restriction** and **exchange**).



Wu D, Jiang K, Li H et al, Radiology (2022)

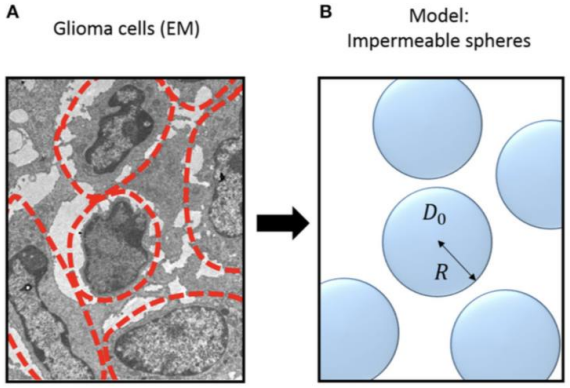


TIME REGIME: short t_d → intermediate t_d → long t_d

SEQUENCE: OGSE → PGSE → STEAM

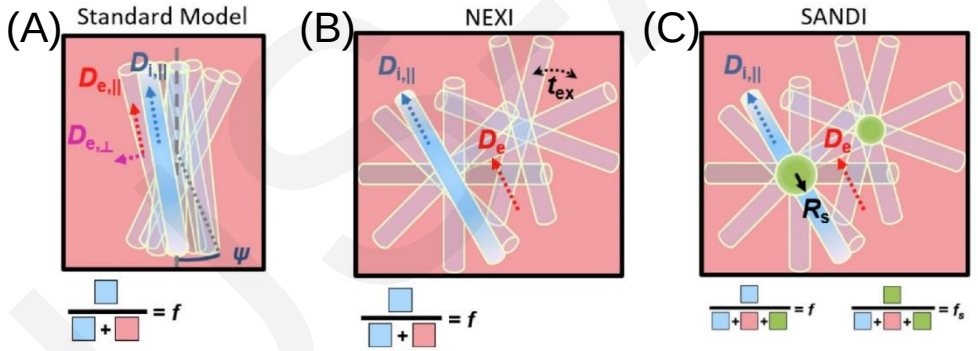
MICROSTRUCTURE MODELING OF TDDMRI

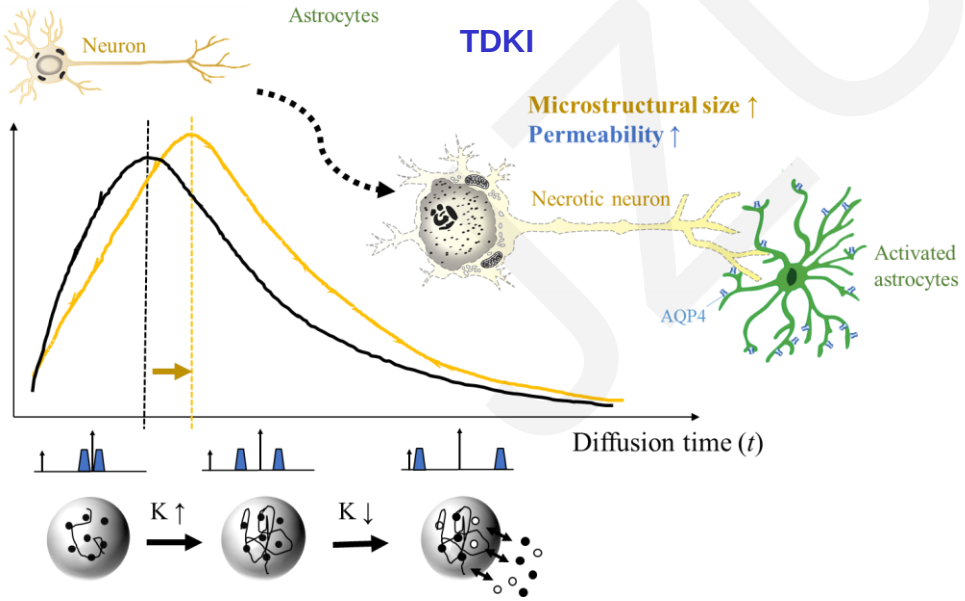
- The development of accurate **mathematical models** and **computational methods** has bolstered theoretical support for TDDMRI and **elevated our understanding of molecular diffusion**.



IMPULSED

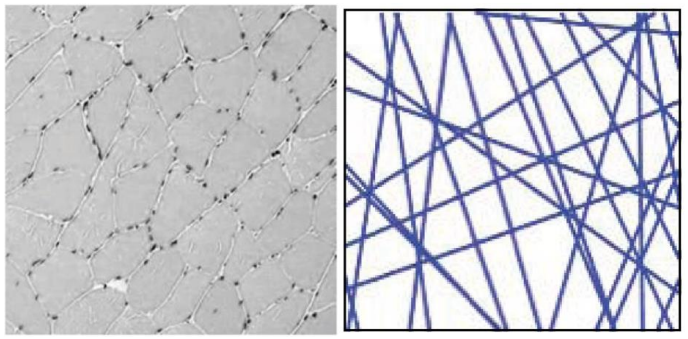
RESTRICTION MODELS





TDKI

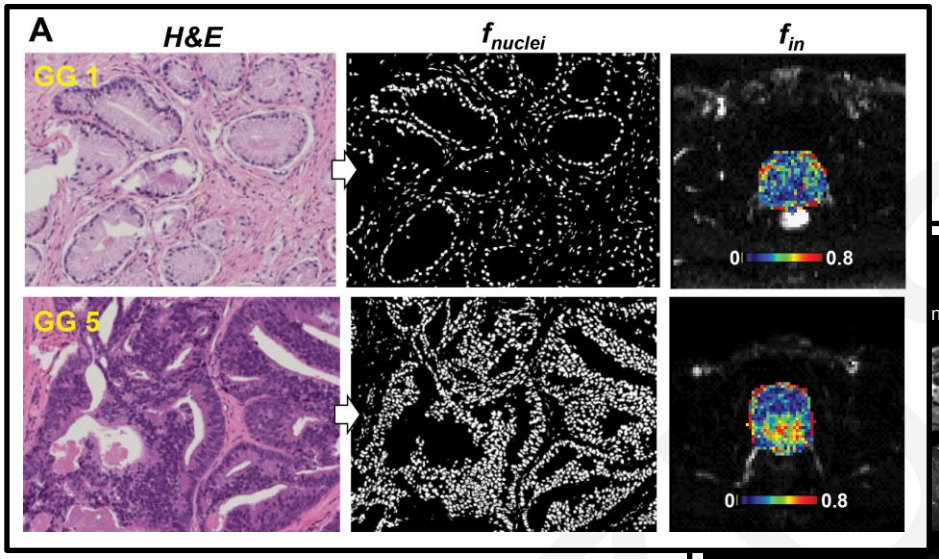
RPBM



EXCHANGE MODELS

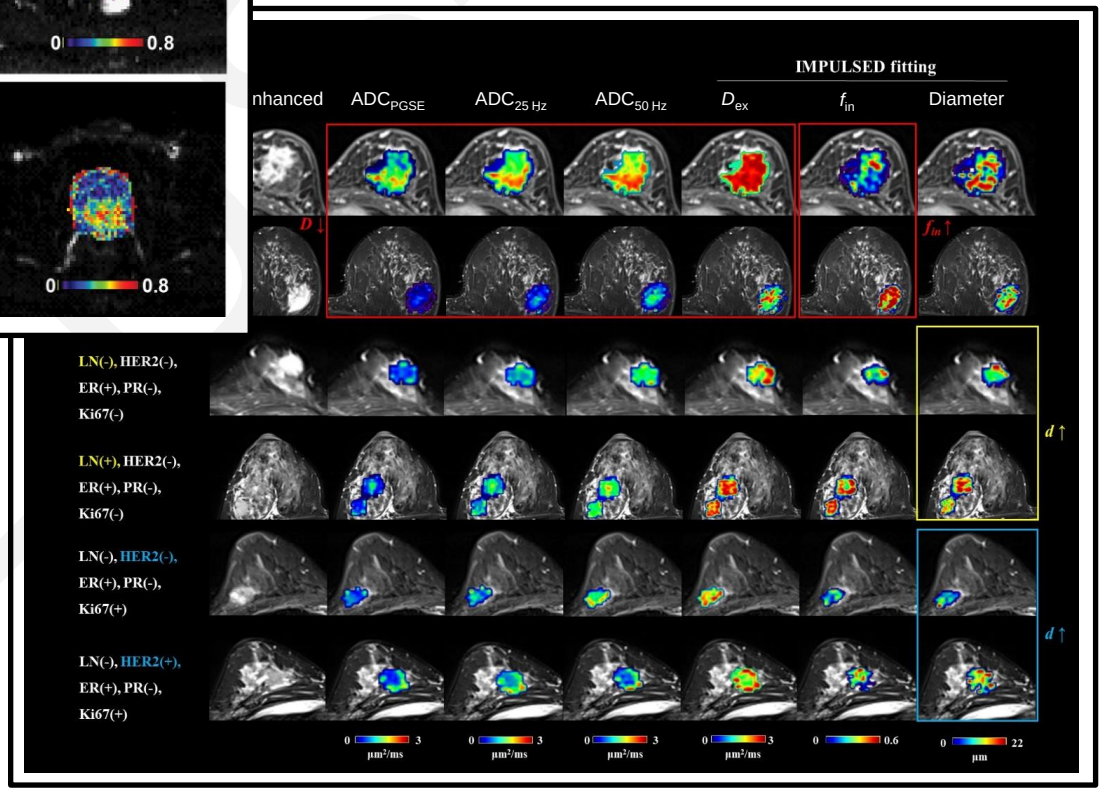
CLINICAL APPLICATION OF TDDMRI

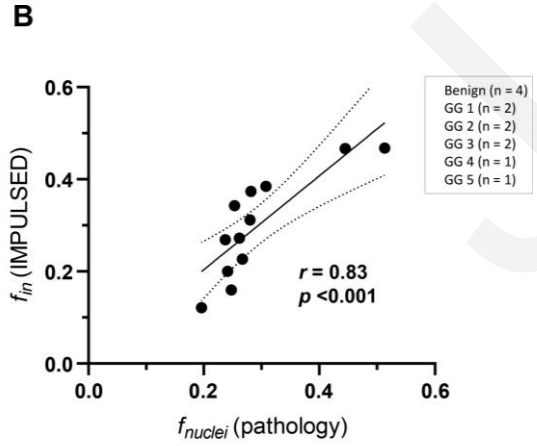
- **The short t_d** provides powerful **candidate indicators** for the specific and non-invasive description of the **cellular structural features** of brain neurons, various tissue cells, and tumor cells, offering greater sensitivity for **detecting disease diagnosis, treatment and progression** .



Prostate cancer microstructure imaging and grade classification

RESTRICTION MODELS

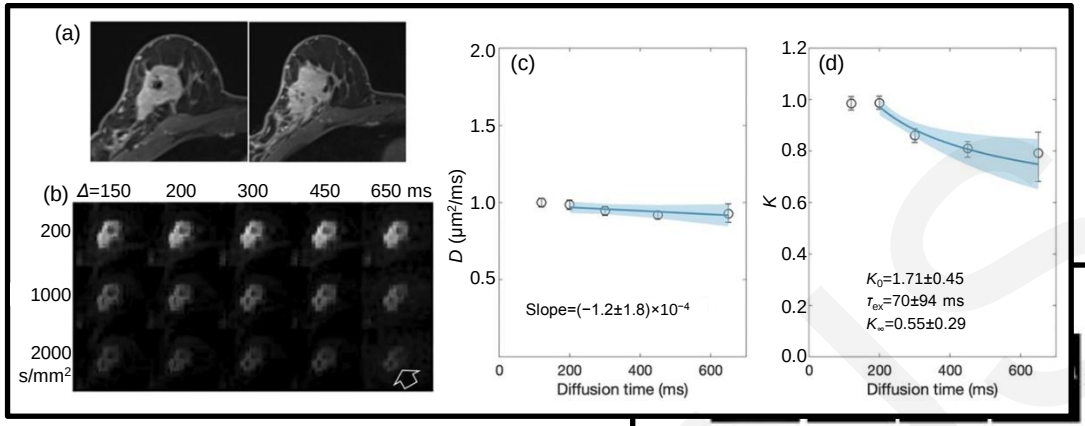




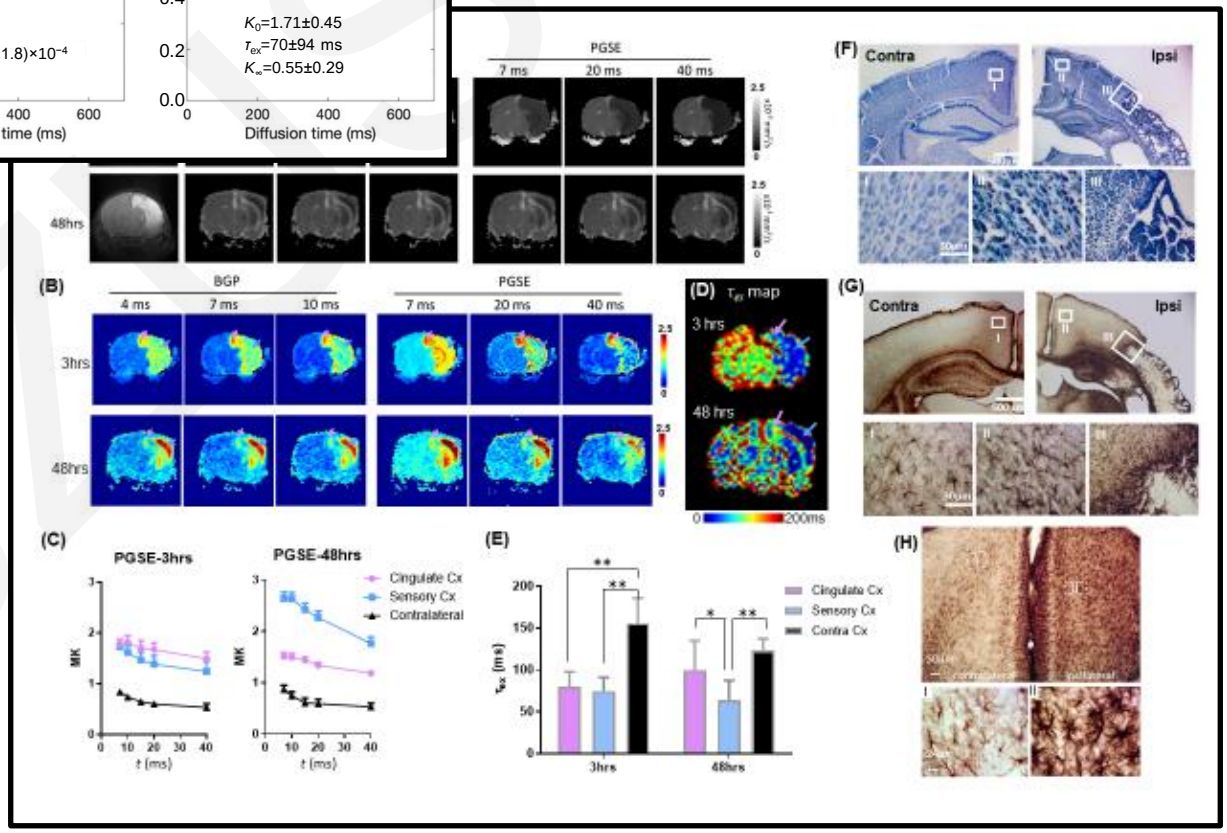
Breast cancer microstructure imaging and molecular subtypes classification

CLINICAL APPLICATION OF TDDMRI

- **The long t_d** provides an angle to noninvasively infer the **global diffusion dimension** of water molecules and insights include **identifying mesoscale structures** affecting water diffusion in muscle and brain tissue through **changes in membrane permeability.**



EXCHANGE MODELS



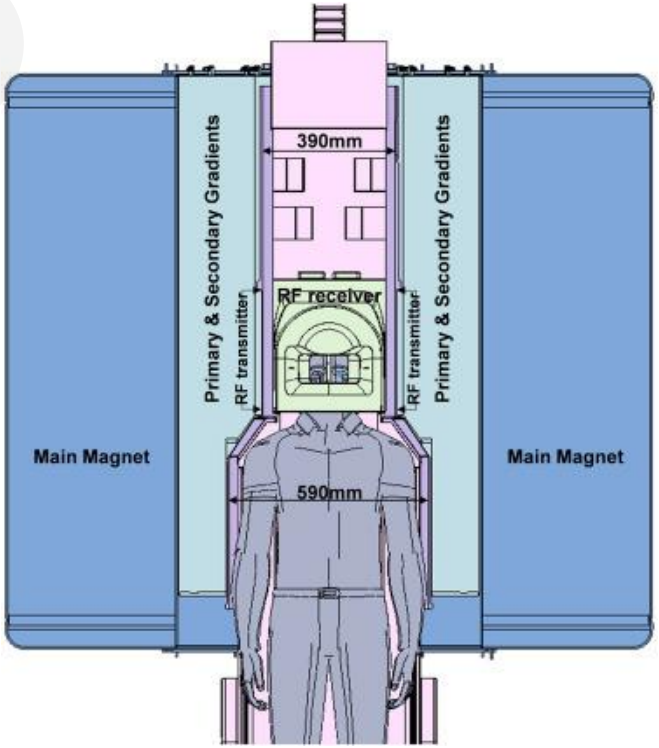
tDKI-based estimations of trans-membrane water exchange in a mouse model of neonatal HI injury.

FUTURE DEVELOPMENTS OF TDDMRI

- **Hardware and acquisition**
  1. extension of the diffusion time spectrum
  2. enhance dMRI contrast
  3. avoid undesired effects

- **Optimization of models**
  1. Provide meaningful biomarkers and contrast
  2. Evolve understanding
  3. Improve model fitting strategy
  4. Validation is important

- **Clinical translation**
  1. Standardization
  2. Tolerable scan settings



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