Diffusion phantom

The **Diffusion Phantom** is a device used to demonstrate the diffusion that takes place in the brain. Using diffusion measurements MRI it is possible to obtain values corresponding to the human brain in a given phantom.

Introduction

In magnetic resonance imaging research, healthy volunteers are suitable and often used, as the brain generally provides a **realistic image of the clinical object**. Values of **mean diffusivity MD** and **fractional anisotropy FA** are obtained using diffusion imaging **DTI**. MD and FA values are explained later in the text.

In addition to many advantages such as availability, realistic depiction, the use of live volunteers has its limitations, the **limiting factors**. Most often, this is **movement of volunteers** during longer measurements, but also **movement due to breathing and heartbeats**. All these unwanted effects force us to look for more reliable objects to measure.

A possibility in this area is the construction and subsequent use of a diffusion MRI test object, a phantom. It is important that we can measure the parameters for isotropic diffusion (MD) and anisotropic diffusion (FA) using the diffusion phantom. Currently, there are several types of phantoms used in **DTI**, each with its own advantages and disadvantages.

Divided diffusion phantoms


Diffusion Phantom

Phantoms are divided according to the material used and construction into:

1. Phantom for measuring mean MD diffusivity;
2. Phantom to measure FA fractional anisotropy;

- Plant phantoms;
- Capillary phantoms;
- Fiber phantoms.

Phantom for measuring mean MD diffusivity

The **MD value** in the human body indicates how much the free diffusion of water is hindered by physiological barriers such as the cell wall. To achieve similar values in the phantom, it is necessary to use a suitable isotropic liquid for its construction.

Liquid	MD [$*10^{-9} m^2 s^{-1}$]	Benefits	Disadvantages
Water (22°C)	2.1	non-toxic, easily available	MD higher than in the brain
Ice water (1°C)	1.1	non-toxic, readily available, MD values similar to MS lesions	MD higher than in the brain
Viscous aqueous solution			
Sucrose	1.1	non-toxic, readily available, MD values similar to MS lesions	MD higher than in brain, one extra spectral line from sucrose
Cyclic hydrocarbons			
Cyclohexane	1.39	MD values similar to MS lesions	highly flammable, high MD value
Cycloheptane	0.93	MD values similar to brain	highly flammable
N-alkanes			
Dean	1.31	MD values similar to MS lesions	flammable

Phantom for measurement of FA fractional anisotropy

Fractional anisotropy FA is a scalar quantity with values between 0 and 1. It shows the degree of anisotropy in the diffusion process. Values close to zero mean that diffusion is isotropic, unbounded, in the given region. Values close to one indicate limited diffusion, along all directions. In addition to FA, it is also possible to measure MD in these phantoms. The table shows FA and MD values for all three types of phantoms.

Material	MD [*$10^{-9}$$m^2$ s^{-1}]	FA
Asparagus	1.3±0.01	0.2±0.01
Glass capillaries	1.4±0.2	0.5±0.1
Hemp	1.7±0.6	0.2±0.1
Polyamide	1.4±0.1	0.3±0.1
White matter of the brain	0.69-0.93	0.4-0.8

Of the phantoms listed in the table, the phantom constructed from Dyneema fibers appears to be the best, since the measured values of **MD** and **FA** best correspond to the in vivo environment, i.e. the environment in the white matter of the brain.

Summary

Diffusion imaging continues to find new applications. Due to the sensitivity of diffusion, MRI is able to detect very small changes at the molecular level. For this, diffusion phantoms are capable of providing MD and FA values close to in vivo values. The advantage of phantoms is that they are generally more stable and their structure is easier to understand than that of plants or humans.

Links

- Diffusion
- Nuclear Magnetic Resonance

References

- JONES, Derek K. *Diffusion MRI : theory, methods, and applications.* 1. edition. Oxford University Press, 2011. ISBN 9780195369779.
- NAHALKA, Dávid. *MR zobrazování tenzoru difúze (DTI)* [online]. Brno, 2004, Available from <https://is.muni.cz/th/rjgvp/BP_Nahalka_DTI.pdf?so=nx>. Bakalářská práce