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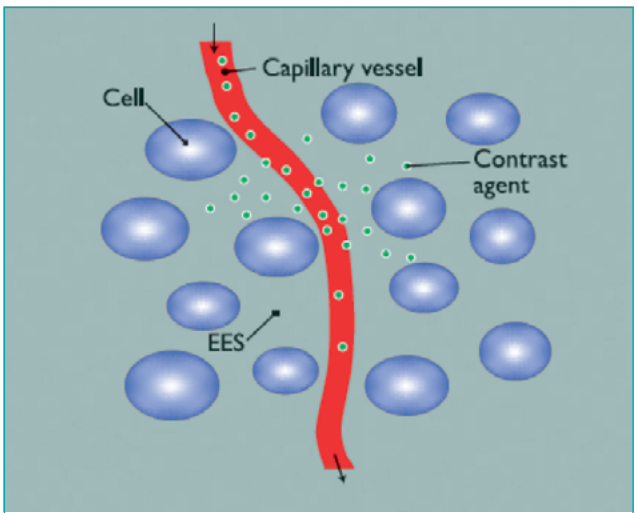
Vascular permeability depends on tissue and its condition

Fast cell growth requires extra blood and nutrient supply and is often characterized by angiogenesis (growth of extra blood vessels from existing vessels). Angiogenesis is a process that occurs in tissue growth and repair.

Angiogenesis is often accompanied by increased vascular permeability. Vascular permeability is the ability of a blood vessel wall to allow molecules to pass through. Permeability depends on tissue type and organ.

In a healthy brain the blood brain barrier (BBB) effectively separates circulating blood from the extracellular fluid in the central nervous system. This means that the vessel wall restricts diffusion of larger objects like bacteria and certain molecules into the brain. Only small molecules like O_2, hormones and CO_2 can pass into the tissue. Therefore, the measured permeability in a healthy brain is very low, close to zero.

The vessels in other organs, for instance the prostate, are much more permeable, with values larger than zero.



Schematic representation of physiology related to flow and permeability in blood vessels. Depending on the tissue characteristics, some of the contrast agent leaks into the extravascular extracellular space (EES). The MR contrast agent does not enter the cells, but will wash in and out of the EES.

Acquisition and processing of MR data for calculating permeability

Based on MR data, the MR Permeability tool on IntelliSpace Portal can be used to determine the leakage of contrast agent (gadolinium chelates) into the extra-vascular, extracellular space (EES). The most important use is currently in prostate and brain.

The MR scanning starts with two separate 3D T1-weighted scans with different flip angles to determine the T1 relaxation time of the tissue. Then, Dynamic Contrast Enhanced (DCE) imaging is performed with high spatial and high temporal resolution [1].

The Permeability analysis tool will automatically combine the 3D T1-weighted and DCE series to immediately provide permeability results. An important choice for the calculation is the Arterial Input Function (AIF) used to fit all results to the Tofts model [1]. The MR Permeability package provides two ways to define the AIF: based on the injection protocol or based on actual DCE data.

The MR Permeability tool calculates permeability maps, but it also conveniently provides color maps that combine the quantitative results with the source data and with anatomical data – typically T2-weighted and diffusion images – always geometrically aligned with the original DCE acquisition.

Permeability parameters

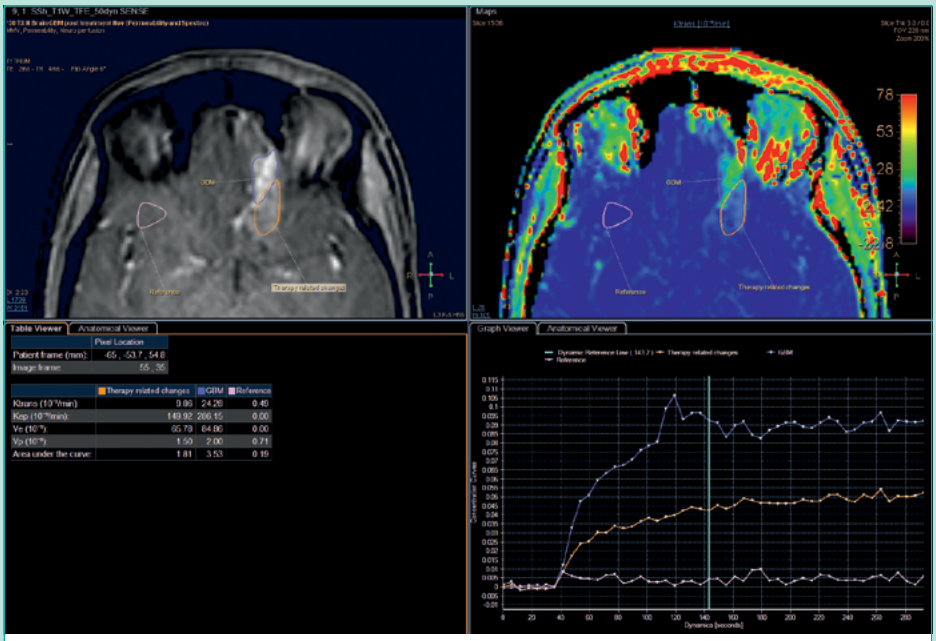
Based on the Tofts model [1], the MR Permeability tool provides maps of the kinetic parameters K^{trans} and K_{ep}.

K^{trans} describes the transfer of the diffusible tracer (contrast agent) into the EES. This transfer will depend largely on the permeability, and also on the flow of the blood plasma that carries the contrast agent.

K_{ep} describes the efflux of the same tracer from the EES back to the blood plasma. This efflux rate depends on permeability, but also on the EES volume compared to the blood plasma volume: a tissue with a small percentage of EES will have a relatively large vessel wall area to enable the efflux.

"The MR Permeability analysis from Philips is an easy tool for quantification of permeability and will allow independent groups to characterize prostate lesions and, hopefully, improve diagnostics and patient management."

Dr. O. Rouvière, Edouard Herriot Hospital, Lyon, France



An 18-year-old female underwent surgical resection in the frontobasal region and combined radio/chemotherapy. Three months post-radiotherapy, MRI shows enhancement. DCE-perfusion shows regions with lower forms of leakage (orange ROI and curve), indicative of therapy-related changes. Six weeks later MRI also shows a further reduced enhancement in these regions.
Courtesy Leuven University Hospitals, Belgium.

Permeability analysis in brain

In brain imaging, permeability analysis may be an important addition to anatomical imaging to detect areas with changes in permeability.

"This technique uses T1-weighted acquisition, which does not suffer from susceptibility artifacts – as experienced with EPI-based sequences like T2* perfusion – which can make proper diagnosis of e.g. the frontobasal region very challenging. This can be of considerable importance, especially in post-surgery patients where the absence of distortions due to suture material and/or blood deposits allows a cleaner read and analysis of the images."

"Differentiation of therapy-related tissue changes is often challenging. Values like K^{trans} and K_{ep} by themselves do not provide an absolute truth, but they can help in monitoring of therapy effectiveness, especially when used in a multimodal approach."

Dr. S. van Cauter, University Hospitals Leuven, Belgium

This article is based on the white paper *Extra window in oncology with vascular permeability analysis* by S van Cauter, MD, PhD (University Hospitals Leuven), O Rouvière, MD, PhD (Edouard Herriot Hospital, Lyon), U van der Heide, MD, SWTPJ Heijmink, MD (The Netherlands Cancer Institute – Antoni van Leeuwenhoek Hospital, Amsterdam), FGC Hoogenraad, PhD (Philips Healthcare).

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