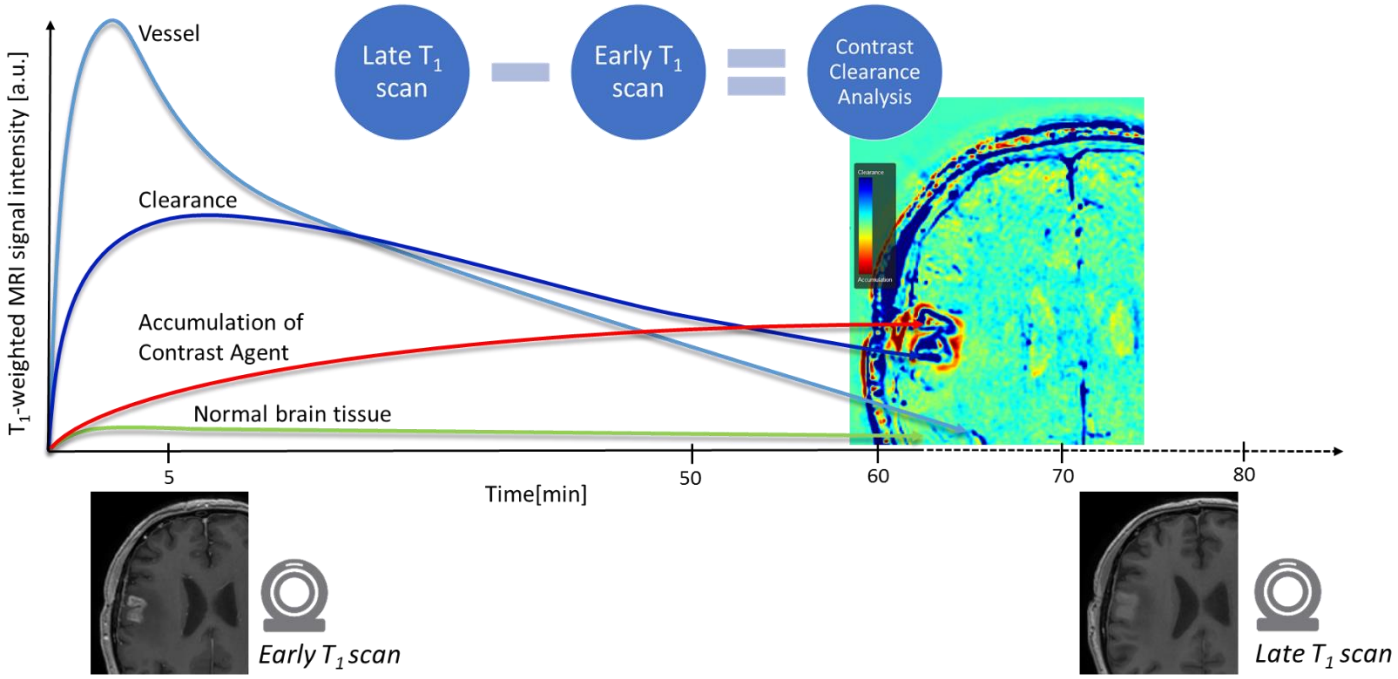
BRAINLAB

Elements Contrast Clearance Analysis

Technical Background

MRI is a well-established technique to display and inspect a patient's soft tissue anatomy. While contrast-enhanced MRI highlights areas of high vascular activity, like vessels, delayed-contrast MRI could be used to identify areas of low activity. Elements Contrast Clearance Analysis makes use of both imaging techniques to facilitate high resolution differentiation of these regions, helping to discern areas of contrast agent clearance and contrast agent accumulation.



The contrast clearance analysis is performed by subtracting T_1-weighted MRIs acquired 60-105 min after Gadolinium (Gd)-based contrast agent (CA) injection from those acquired 5 min post-Gd. The derived color-coded high resolution maps provide effective separation between areas of CA accumulation (illustrated in red), and areas of CA clearance (illustrated in blue).

Validation: The contrast clearance analysis is performed by subtracting T_1-weighted MRI scans acquired at two time points after a standard Gadolinium-based contrast agent injection. Pilot clinical research indicates that areas of accumulation (i.e. low clearance rate) are depicted in red and morphologically active areas (high clearance rate) in blue[1,2]. In a recent study, such an approach was validated by comparing the pre-surgical maps with histology in $n = 51$ resected patients with primary and metastatic brain tumors, resulting in 100% sensitivity and 92% positive predictive value (PPV) to morphologically active tumor [2].

Rational: Once injected, the contrast agent spreads rapidly throughout the blood system and then clears through the kidneys within a couple of hours. Therefore, vessels typically show rapid increase in signal intensity followed by a relatively rapid clearance (light blue curve in the graph). Subtraction of signal intensities in voxels, including vessels, is thus negative (*depicted in blue*). Other areas or pathologies affected by viable/dense vasculature also typically show a rapid signal rise followed by a relatively rapid clearance, although the peak intensity is delayed due to blood-brain barrier disruption (dark blue curve). The subtraction is negative (*blue*) as well. Areas affected by e.g. damaged vasculature typically show slow accumulation of contrast (red curve in the graph), and thus the subtraction is positive (*depicted in red*). ***Please note*** that vascular malformations may mimic morphologically active areas, as vessels and such regions appear blue in the analysis results.

Data Acquisition Protocol: IV bolus injection of a Gd-based contrast agent (standard dose, 0.1mmol/kg) is required. 3D T_1-weighted MRI (MPRAGE, FSPGR, VIBE, SPACE, etc.) should be acquired approx. 5 min post-Gd and then again 60-105 min post-Gd (the patient is allowed to leave the MRI between both scans). ***Please note:*** It is important that the early time point is at a fixed time post-Gd injection, therefore, it is best to acquire it after a fixed protocol, e.g., after DSC-MRI and 2D spin-echo or after DCE-MRI. The timing of the late time point is flexible and can change from one follow-up to the next as long as it is acquired between 60-105 min post-Gd. It is also important that the T_1-weighting of the MRI sequence does not change between the two acquisitions; thus the exact same protocol should be used for both scans (same FOV, slab size, etc.). Furthermore, poor image quality or metal-induced artifacts may affect the interpretation of the Contrast Clearance Analysis.

Elements Contrast Clearance Analysis automatically conducts the analysis by means of RF inhomogeneity correction, rigid image fusion and color-coded subtraction mapping. For color-coding, the patented Brainlab Synthetic Tissue Model is used to segment the brain anatomies and to determine the mean signal intensities in the brain and within the largest vessel cluster (the latter is found via connected component analysis within the brain mask). The brain signal is used to normalize both post-Gd scans and the vessel dynamic (mean subtraction value), which determines the red-blue color-coding. In particular, negative (high clearance rate) and positive subtraction values (low clearance rate, accumulation at the delayed time point) are linearly mapped to blue and red, respectively, while restricting the maximum values to ±30% of the vessel dynamic. Finally, the high-resolution maps are stored in RGB DICOM file format.

References

[1] Zach L. et al. PLOS One. 2012;7(12):e52008
[2] Zach L. et al. Neuro Oncol. 2015 Mar;17(3):457-65

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