Proton magnetic resonance spectroscopic imaging

Magnetic resonance spectroscopic imaging (MRSI) is a noninvasive imaging method that provides spectroscopic information in addition to the image that is generated by MRI alone.

Whereas traditional magnetic resonance imaging (MRI) generates a black-and-white image in which brightness is determined primarily by the T1 or T2 relaxation times of the tissue being imaged, the spectroscopic information obtained in an MRSI study can be used to infer further information about cellular activity (metabolic information). For example, in the context of oncology, an MRI scan may reveal the shape and size of a tumor, while an MRSI study provides additional information about the metabolic activity occurring in the tumor. MRSI can be performed on a standard MRI scanner, and the patient experience is the same for MRSI as for MRI. MRSI has broad applications in medicine, including oncology and general physiological studies.

When hydrogen is the target element, MRSI is also called 1H-nuclear magnetic resonance spectroscopic imaging and proton magnetic resonance spectroscopic imaging. MRSI can also be performed with phosphorus or hyperpolarized carbon-13.

Proton magnetic resonance spectroscopic imaging (Proton magnetic resonance spectroscopic imagingI) enables the assessment of the spatial distribution of several brain metabolites.

Important peaks

Lactate: a couplet peak. Not present in normal brain. End product of anaerobic glycolysis, ∴ a marker of hypoxia. Present in: ischemia, infection, demyelinating disease, inborn errors of metabolism… At higher TE (e.g. TE = 144), the peak inverts which can help distinguish it from the lipid peak.

↓ NAA, ↑ lactate, ↑ lipid, ↑choline (rule of thumb: with gliomas, the higher the choline, the higher the grade up to grade 3, thereafter necrosis reduces relative choline levels and the lipid peak may be utilized).

Stroke:↑ lactate peak predominates. Choline is characteristically low.

Abscess: Reduced NAA, Cr & choline peaks, and “atypical peaks” (succinate, acetate…) from bacterial synthesis is pathognomonic for abscess (not always present). Lactate may be elevated.

Multiple sclerosis: Bland pattern. NAA slightly reduced. Lactate and lipid slightly elevated.Choline not elevated

in AIDS: may be able to help differentiate toxo from lymphoma from PML (PML: ↓ NAA, no significant increase in choline, lactate or lipid)

Utility

Proton magnetic resonance spectroscopic imagingI is valuable for differentiating active tumor from normal tissue, edema or necrosis, and may improve the identification of the spatial extent and characteristics of brain tumors [1) 2) 3) 4) 5) 6)].

Preoperative tumour grading is imperative owing to difference in invasive, aggressive tendencies of different grades of glial tumours implying varied prognosis, therapeutic options. Histopathological examination has inherent sampling errors. Magnetic Resonance Spectroscopy (MRS) and Diffusion Weighted Imaging (DWI) can provide non invasive information about internal mileu hence, aiding in tumour grading by adding to information provided by conventional MRI sequences.

Both DWI as well as MRS were found to have statistically significant roles in grading of glial brain tumours. MRS was found to be more useful than DWI [7)].

Brain abscess

Proton magnetic resonance spectroscopy (PMRS) has high sensitivity and specificity for the detection of pyogenic brain abscess and the categorization of bacteria. But the metabolite patterns failed to evaluate the etiology of disease when the culture results are sterile.

Based on metabolite resonances, PMRS can detect slow growing and fastidious organisms and classify them into aerobic and anaerobic bacteria which are difficult to culture by conventional method. It can categorize microorganisms even in culture sterile samples with rational sensitivity and specificity which may allow early choice of targeted therapy [8)].

Neuronavigation

3D MR spectroscopy techniques allow for improved correlation of metabolite profiles with specific regions of interest in anatomical tumor images, which can be useful in characterizing and treating heterogeneous tumors that appear structurally homogeneous.

Kanberoglu et al., develop a clinical workflow and uniquely capable custom software tool to integrate advanced 3-tesla 3D proton magnetic resonance spectroscopic imaging (Proton magnetic resonance spectroscopic imagingI) into industry standard image-guided neuronavigation systems, especially for use in brain tumor surgery.

Proton magnetic resonance spectroscopic imagingI spectra from preoperative scanning on 15 patients with recurrent or newly diagnosed meningiomas were processed and analyzed, and specific voxels were selected based on their chemical contents. 3D neuronavigation overlays were then generated and applied to anatomical image data in the operating room. The proposed 3D methods fully account for scanner calibration and comprise tools that we have now made publicly available.

The new methods were quantitatively validated through a phantom study and applied successfully to

mitigate biopsy uncertainty in a clinical study of meningiomas.

The proposed methods improve upon the current state of the art in neuronavigation through the use of detailed 3D Proton magnetic resonance spectroscopic imagingI data. Specifically, 3D MRSI-based overlays provide comprehensive, quantitative visual cues and location information during neurosurgery, enabling a progressive new form of online spectroscopy-guided neuronavigation [9].

Temporal lobe epilepsy

Proton MRS detected altered ipsilateral temporal pole metabolism in patients with unilateral MTS [10].

Magnetic resonance spectroscopy is a promising tool in evaluating patients with epilepsy and offers increased sensitivity to detect temporal pathology that is not obvious on structural MRI imaging [11] [12].

In MRI-negative TLE, significant reductions in the NAA/Cr and NAA/(Cr+Cho) ratios ipsilateral to the seizure side may help lateralize and localize the epileptogenic zone [13].

Alzheimer Disease

see Proton magnetic resonance spectroscopic imaging for alzheimer disease

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