Single voxel proton resonance spectroscopy as a method for the classification of brain tumors using artificial neural networks

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Introduction:

Magnetic resonance tomography allows a relatively exact localization of brain lesions. However, it is often very difficult to make a correct differential diagnosis of the detected lesion only on the basis of the MR images. An astrocytoma (WHO III), for example, can show tissue with the same intensity of contrast enhancement as a glioblastoma (WHO IV), while astrocytomas (WHO I) and astrocytomas (WHO II) do not show this characteristic at all. Brain abcesses often show a similar appearance as cystic or necrotic parts of a brain tumor. The therapeutic decision primarily depends on the location and the kind of the tumor, but also on the size and the growth speed. Today, a histological examination of the tissue requiring an invasive biopsy with immanent risks is a prerequisite to securely classify a detected brain tumor. ^{1}H MR spectroscopy may help to differentiate tumor types because it offers the possibility to detect and to quantify (relatively) a set of metabolites within a selected tissue region. The acquired spectra can give information on the tissue "status" and may thus allow a "virtual biopsy" in the future.

Method:

20 patients, 15 men and 5 women (46.1 ± 13.6 years), with a histologically confirmed diagnosis (biopsy) of a brain tumor were examined. Three patients had an astrocytoma (WHO II), five patients an astrocytoma (WHO III) and 12 patients a glioblastoma (WHO IV). On average, the biopsy was 16.5 months ago (1-54 months). Additionally, the spectra of 18 healthy volunteers, 9 men and 9 women, were examined on a 1.5 T Magnetom Symphony (Siemens AG, Germany). The spectroscopic acquisition was supplemented by a routine MR follow up including the administration of contrast agent. The patients consented to the extra time needed for the MR spectroscopy. In addition, all test persons gave their consent to the examination. After the routine investigation of the patients one volume element for spectroscopy was placed inside the tumor tissue with the help of the routinely acquired T_1-sequences (fig.1a). Furthermore, a reference voxel was acquired at the contra lateral position inside the normal brain tissue (fig.1b).

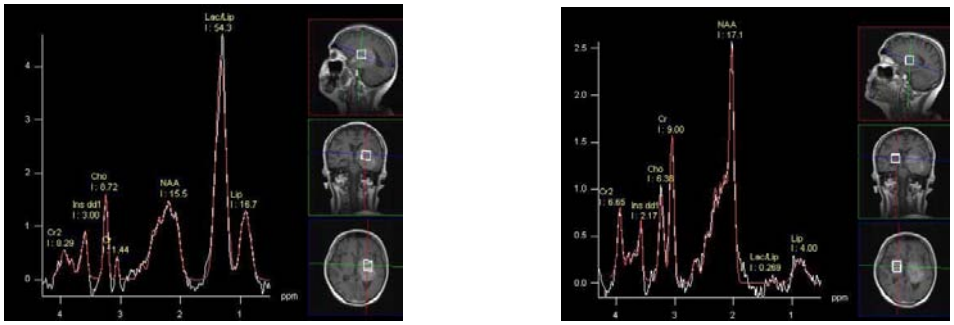

Figure. 1: Spectrum of the SVS Voxel and placement inside the tumor (a) and contra lateral tissue (b)

Spectra were acquired by "point resolved spectroscopy" (PRESS) with TE=30ms, TR=1500ms and 128 acquisitions. Totally, 236 spectra of the patients and volunteers have been evaluated. The data acquisition as well as the post-processing was carried out completely automatically without manual shim or manual post-processing corrections. The post-processing protocol contained a base line and a linear phase correction as well as a curve fit. All integral or normalized integral values of the metabolites (creatine, choline, NAA, Ins dd, creatine 2, lactat/lipid and lipid) were fed to a "back propagation of error"-type (BPE) artificial neural network for classification. With a sufficient number of examples with a known classification, the BPE neural net "learns" to extract the basic features defining a class and then uses the "acquired experience" for the classification of other cases. The "learning" process is called training, whereas the classification of untrained data with an also known classification is called test. For training and test, the entire number of spectra was divided into three groups. Each group contains a similar number of spectra of all different tumor categories (astrocytoma, glioblastoma and normal brain tissue). Two groups were used as training data, whereas the third independent group afterwards tests the trained network. This approach allows to build three different training sets with the corresponding data for testing the net.

Results:

In all three test groups, 1% of all test patterns could not be trained to classify one of the three classes correctly using the integral values of the metabolites. This not trainable classification may result from "tumor class" changes after biopsy. With the integral normalized to creatine, this value increases up to 2%. The tests after training classify an average of 8% of the untrained purely integral data as wrong, whereas the value for normalized integrals slightly increases up to 9%. This means the trained network is able to classify more than 90% of all untrained test spectra correctly. The results of the normalized spectra are slightly worse than those of integral values. This findings are a hint that creatine should not be used as an internal standard, although creatine is often used as such a standard.

Conclusion:

^{1}H MR single voxel volume spectra with a short echo time of 30 ms can help to differentiate between various brain tumors using "back propagation" artificial neural networks as classifiers. The excellent result of the classification using single voxel spectroscopy suggests an extension to chemical shift imaging. Moreover, the classification results of unsupervised learning algorithms (self organizing maps) should be compared to the used algorithm.