Proton magnetic resonance spectroscopy (1H-MRS) for the evaluation of treatment of brain tumours

Abstract We investigated metabolic changes in brain tumours following treatment, using proton magnetic resonance spectroscopy. In meningiomas, effective therapeutic embolisation led to an acute increase in lactate. In radiosensitive tumours such as malignant lymphoma, a decrease in lactate and an increase in N-acetyl-aspartate occurred after radiotherapy, which preceded changes observed on magnetic resonance imaging. On the other hand, no significant changes in spectral patterns were observed in malignant gliomas resistant to therapy. Tissue characterisation of brain tumours by spectral patterns on proton magnetic resonance spectroscopy remains controversial. However, we have shown it to be sensitive to metabolic changes following treatment, which may reflect the efficacy of the therapy.

Key words Magnetic resonance spectroscopy · Brain tumours · N-acetyl-aspartate · Lactate · Embolisation

Introduction

Magnetic resonance spectroscopy (MRS) has opened the way for noninvasive study of the metabolism of the human brain [1, 2]. In particular, proton MRS (1H-MRS) has a high signal-to-noise ratio and spatial resolution satisfactory for clinical application [2, 3]. Using this new modality, many aspects of brain tumour metabolism have been revealed, which had not previously been demonstrated with conventional neuroimaging techniques or laboratory examinations [3-5]. However, tissue characterisation of brain tumours on the basis of spectral patterns has been unsuccessful [6, 7].

We reported that in cerebral infarcts, changes in the spectral pattern are more sensitive than computed tomography (CT) or magnetic resonance imaging (MRI) [8, 9]. Thus, metabolic change revealed by 1H-MRS might be a sensitive means of evaluating treatments for brain tumours. Our purpose was to study metabolic changes occurring with treatment of brain tumours, using 1H-MRS.

Patients and methods

Localised 1H-MRS was performed on a 1.5 T magnetic resonance system. Before acquisition of the signal for MRS, routine MRI (T1-weighted coronal and T2- and proton-density-weighted transverse image) were obtained. Contrast-enhanced T1-weighted images were obtained after intravenous Gd-DTPA (0.1 mmol/kg) to discriminate enhancing tumour from surrounding oedema. A 27 cm³ (3 × 3 × 3 cm) or 8 cm³ (2 × 2 × 2 cm) volume of interest (VOI) was placed centrally in the tumour. We obtained a localised signal using the stimulated echo acquisition mode (STEAM) developed by Frahm et al. [2, 3]. Suppression of the water proton signal was achieved by a chemical shift selective (CHESS) pulse. Repetition time (TR) was 1500 ms and echo time (TE) 270 ms. Free induction decay (FID) signals were collected 500 times and the total acquisition time was 15 min. Consequently the total examination time (including imaging) was about 45 min, which was considered to be reasonable for clinical examination for patients with brain tumours.

The spin-echo time was set to 270 ms to provide in-phase conditions for lactate methyl group doublet (spin-spin coupling constant J = 7.35 Hz). When a typical doublet peak of lactate (Lac) was recognised, all other peaks were assigned using the chemical shift of lactate (1.33 ppm). When lactate could not be assigned, other signals such as choline (Cho) (chemical shift 3.20 ppm) or N-
Pre-operative embolisation of meningiomas (4 cases)

Successful embolisation of the feeding artery to meningiomas led to a drastic change in the spectrum in 3 cases (Fig.1). In one, the spectrum before embolisation showed a high Cho signal but no significant Lac signal. Six hours after embolisation of the feeding artery, the Cho signal decreased slightly and the Lac signal increased acutely. This change suggested ischaemic damage induced by embolisation, resembling the spectral change seen in the acute stage of cerebral infarction. MRI revealed no significant change 6 h after this successful embolisation (Fig.1). The day after embolisation, at surgery most of the tumour was necrotic and was excised without significant bleeding.

In contrast, in one case of adequate embolisation, the spectrum showed no significant change (Fig.2), and surgery the next day revealed recanalisation of the feeding middle meningeal artery.

Chemotherapy and radiotherapy for glioblastoma and high-grade astrocytoma (5 cases)

In most cases, follow-up 1H-MRS after chemotherapy and radiotherapy showed no significant changes. In one case, following radio- and chemotherapy, a small NAA signal was noted, but no significant changes were observed in Cho or Lac (Fig.3).

Radiotherapy for malignant lymphoma (2 cases)

A drastic change was observed on 1H-MRS (Fig.4). Before radiotherapy, high Cho and Lac and low NAA peaks were observed; this is a nonspecific brain tumour pattern. However, after 750 Gy radiation, the spectral pattern showed an obvious increase in NAA and a decrease in Lac. These changes were observed before any change was seen on MRI. After 2000 Gy, the spectra showed an almost normal brain stem pattern (high Cho level compared to NAA and phosphocreatine/creatine, and no Lac (Fig.5) and MRI revealed a decrease in the size of the contrast enhancing mass.