Clinical Neurology and Neurosurgery 111 (2009) 527–535

Contents lists available at ScienceDirect

Clinical Neurology and Neurosurgery

journal homepage: www.elsevier.com/locate/clineuro

Spectroscopy-supported frame-based image-guided stereotactic biopsy of parenchymal brain lesions: Comparative evaluation of diagnostic yield and diagnostic accuracy

Mikhail F. Chernov[a,b,d,*], Yoshihiro Muragaki[b,d], Taku Ochiai[b], Takaomi Taira[b], Yuko Ono[c], Masao Usukura[c], Takashi Maruyama[b,d], Kotaro Nakaya[b], Ryoichi Nakamura[a,d], Hiroshi Iseki[a,b,d], Osami Kubo[b], Tomokatsu Hori[b], Kintomo Takakura[a,b,d]

[a] International Research and Educational Institute for Integrated Medical Sciences (IREIIMS), Tokyo Women's Medical University, Tokyo, Japan
[b] Department of Neurosurgery, Neurological Institute, Tokyo Women's Medical University, Tokyo, Japan
[c] Department of Neuroradiology, Neurological Institute, Tokyo Women's Medical University, Tokyo, Japan
[d] Faculty of Advanced Techno-Surgery, Institute of Advanced Biomedical Engineering and Science, Tokyo Women's Medical University, Tokyo, Japan

ARTICLE INFO

Article history:
Received 7 October 2008
Received in revised form 16 March 2009
Accepted 20 March 2009

Keywords:
Brain tumor
Stereotactic biopsy
Diagnostic yield
Diagnostic accuracy
Metabolic imaging
Proton magnetic resonance spectroscopy

ABSTRACT

Objective: Comparative evaluation of diagnostic efficacy of stereotactic brain biopsy performed with and without additional use of spectroscopic imaging (^{1}H-MRS) for target selection was done.
Methods: From 2002 to 2006, 30 patients with parenchymal brain lesions underwent ^{1}H-MRS-supported frame-based stereotactic biopsy, whereas in 39 others MRI-guided technique was used. Comparison of diagnostic yield of the procedure in these two groups was performed. Additionally, the diagnostic accuracy was evaluated in 37 lesions, which were surgically resected within 1 month thereafter.
Results: Stereotactic biopsy permitted establishment of a definitive histopathological diagnosis in 57 cases and diagnosis of low-grade glioma without specific tumor typing in 8 cases. In 4 cases tissue sampling was non-diagnostic. In 5 out of 8 cases with incomplete diagnosis and in all non-diagnostic cases target selection was performed without the use of ^{1}H-MRS ($P = 0.2073$). The diagnostic yields of ^{1}H-MRS-supported and MRI-guided procedures were 100% and 90%, respectively ($P = 0.1268$). Comparison of the histopathological diagnoses after stereotactic biopsy and surgical resection revealed complete diagnostic agreement in 13 cases, minor disagreement in 14 cases, and major disagreement in 10 cases. Among these last 10 cases, initial undergrading of non-enhancing WHO grade III gliomas was the most common (7 cases). The diagnostic accuracy of ^{1}H-MRS-supported and MRI-guided procedures was 67% and 79%, respectively ($P = 0.4756$).
Conclusion: While in the present study the diagnostic yield of ^{1}H-MRS-supported frame-based stereotactic brain biopsy was 100%, its statistically significant diagnostic advantages over MRI-guided technique were not proved. Optimal selection of the spectroscopic target for tissue sampling remains unclear.

1. Introduction

Minimally invasive image-guided stereotactic biopsy is a routine neurosurgical procedure that provides an excellent opportunity to establish histopathological diagnosis of parenchymal brain lesions in virtually any location. Introduction of modern neuroimaging and development of computer-based techniques significantly facilitated target selection and navigation during tissue sampling. Nevertheless, from 0.8% to 18.6% of stereotactic biopsies are considered non-diagnostic [1–14]. Moreover, even if histopathological diagnosis is provided, it can significantly differ from that determined after subsequent lesion resection. The rate of such discrepancy varies widely, from 3% to 49% [2,7,11,15–18].

The specific cause of diagnostic failure of stereotactic brain biopsy is the limitation of the structural neuroimaging in the evaluation of the lesion heterogeneity and subsequent suboptimal tissue sampling [8,19–26]. The use of metabolic information provided by positron emission tomography (PET) [18,19,22,24,27–33], single photon emission computed tomography (SPECT) [34], and spectroscopic imaging [20,35–45] for target selection can potentially result in improved diagnostic efficacy of the procedure. However, this has not been investigated in any controlled study. The objective of the present analysis was comparative evaluation of both

* Corresponding author at: International Research and Educational Institute for Integrated Medical Sciences (IREIIMS), Tokyo Women's Medical University, 8-1 Kawada-cho, Shinjuku-ku, Tokyo 162-8666, Japan. Tel.: +81 3 3353 8111x66003; fax: +81 3 5312 1844.
E-mail address: m_chernov@yahoo.com (M.F. Chernov).

0303-8467/$ – see front matter © 2009 Elsevier B.V. All rights reserved.
doi:10.1016/j.clineuro.2009.03.006

diagnostic yield and diagnostic accuracy of the frame-based image-guided stereotactic biopsy of parenchymal brain lesions performed with and without additional use of metabolic data obtained with multivoxel proton magnetic resonance spectroscopy (^{1}H-MRS).

2. Materials and methods

From January 1, 2002 to December 31, 2006, 69 consecutive frame-based image-guided stereotactic biopsies of parenchymal brain lesions were performed in the Department of Neurosurgery of the Tokyo Women's Medical University. In 30 cases ^{1}H-MRS-detected metabolic information was used during target selection, whereas in 39 cases MRI-guided technique was utilized. The method of target selection (with or without the use of spectroscopic imaging) was determined by treating neurosurgeon according to his/her own preference, and no attempt of randomization was made. In both groups of patients, stereotactic biopsy was performed by two neurosurgeons (Drs. T. Ochiai and T. Taira), whereas tumor resection was done by three others (Drs. Y. Muragaki, T. Maruyama, and T. Hori).

One patient underwent stereotactic biopsy twice with an interval of 6 months, which was considered to be two separate cases. Low-grade astrocytoma was diagnosed after the initial MRI-guided procedure. The patient was followed without treatment, but due to rapid tumor progression the tissue sampling was repeated using ^{1}H-MRS support for target selection. At that time the diagnosis of glioblastoma was established. Another patient underwent a course of fractionated radiation therapy (total dose, 50 Gy) for suspected pontine glioma 15 months before stereotactic biopsy. All of the 66 other lesions were either previously untreated or unresponsive to conventional medical therapy, including steroids.

All data for the present analysis were extracted from the constantly maintained surgical, pathological, and radiological databases. For the purpose of the study all MRI and ^{1}H-MRS images were reviewed by a neurosurgeon and a neuroradiologist. Some cases from the same series had been analyzed separately and published previously elsewhere [46].

2.1. Clinical characteristics of patients

There were 45 males and 24 females. Their ages varied from 1 to 78 years (mean, 43 ± 19 years; median, 40 years). The series included 7 pediatric patients, but only one of them was less than 5 years old. According to the regulations of our hospital all patients were tested before surgery for human immunodeficiency virus (HIV), and no positive case was included in the present series.

There were 67 supratentorial and 2 infratentorial lesions. The predominant locations were the cerebral lobe (54 cases), basal ganglia and thalamus (11 cases), corpus callosum, pineal region, pons, and cerebellar hemisphere (1 case in each). Overall, 33 lesions were located on the left side, 32 on the right side, and 4 along the midline.

The majority of lesions (59 cases) had low intensity signal on T_1-weighted images, and high intensity signal on T_2-weighted images. A cyst-like structure of the lesion was noted in 3 cases only. Contrast enhancement was presented in 33 lesions, and was characterized as homogeneous in 8 cases, heterogeneous in 17, ring-like in 4, and patchy in 4.

Comparison of clinical and radiological variables in two groups of patients did not reveal statistically significant differences (Table 1).

2.2. Indications for stereotactic biopsy of parenchymal brain lesions

During the study period not more than 10% of the patients with parenchymal brain lesions underwent stereotactic biopsy in our clinic. The decision to perform tissue sampling was usually made by treating neurosurgeon and approved by the Chairman of the Department (Dr. T. Hori). The indications for the procedure included:

- clarification of the histopathological diagnosis, which could not be established based on clinical and radiological investigations, particularly for the differentiation of neoplastic and non-neoplastic lesions;
- histopathological confirmation of the diagnosis of the tumor, for which treatment with chemotherapy and/or irradiation was planned (for example, malignant lymphoma);
- stereotactic implantation of electrodes for preoperative brain mapping in the cases of gliomas; simultaneous sampling of the neoplasm was usually performed for the consideration of the rationale for its aggressive surgical resection.

Informed consent was obtained from each patient and/or his or her nearest family member. The protocol of ^{1}H-MRS-supported stereotactic brain biopsy was approved by responsible authorities of Tokyo Women's Medical University.

2.3. Neuroradiological guidance

On the day of treatment a Leksell G stereotactic frame (Elekta Instruments AB, Stockholm, Sweden) was fixed on the patient's head under local anesthesia, with the exception of a 1-year-old child, who was under general anesthesia during all stages of the procedure. Axial slices of the plain and contrast-enhanced CT, as well as axial slices of T_2-weighted MRI, and axial, coronal, and sagittal slices of T_1-weighted MRI before and after intravenous injection of single-dose (0.1 mmol/kg) gadoteridol (ProHance®; Eisai Co., Tokyo, Japan), were obtained through each 2 mm under stereotactic conditions. Cerebral angiography was performed in selected cases.

In cases of ^{1}H-MRS-supported stereotactic biopsy, a two-dimensional multivoxel long-echo (TR: 1500 ms, TE: 136 ms) volume-selected spectrum was acquired using double spin-echo acquisition mode, similar to point-resolved spectroscopy (PRESS). Axial postcontrast T_1-weighted MRI was mainly used as a scout image. Under three-dimensional control the ^{1}H-MRS voxel, separated by phase-encoding in 16 rectangular subvoxels (size 15 mm × 15 mm × 15 mm and volume 3.4 cm^3 each), was located on the maximal projection of the lesion. Spatial suppression pulses were applied to the outsides of the voxel to reduce spectral contamination. Global and localized shimming on the water proton and optimization of the water suppression were performed, resulting in water peak line widths of 2–4 Hz. Automatic spectral reconstruction with frequency referencing and application of the zero-level was achieved by software provided by the supplier (MRS-PRO/PX; Toshiba Medical Systems, Tokyo, Japan). Typically, time domain data were zero-filled to 4000 data points and multiplied with a Gaussian function, exponential line broadening was performed, two-dimensional Fourier transformation of the time domain signal into frequency domain signal was done, and baseline and zero-order phase corrections were applied. Metabolite signals from mobile lipids (Lip) [0.8 and 1.3 ppm], lactate (Lac) [1.3 ppm], N-acetylaspartate (NAA) [2.0 ppm], creatine and phosphocreatine (Cr) [3.0 ppm], and choline-containing compounds (Cho) [3.2 ppm] were obtained. Their peak intensity was calculated as an area under the curve. Thereafter, the metabolite ratio of NAA/Cho was calculated in each subvoxel and used for target selection. In the present study, the content of other identified metabolites, namely Lip, Lac, and Cr, was not taken into consideration during tissue sampling.

Both MRI and ^{1}H-MRS were acquired with a 1.5 T clinical imager (ExcellArt; Toshiba Medical Systems, Tokyo, Japan). A brain quadrature (QD) coil (Type MJQH107A–S1A; Toshiba Medical Systems)