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Experiences in surgery of primary malignant brain tumours in the primary sensori-motor cortex practical recommendations and results of a single institution

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ABSTRACT

Objective: Tumour resection in the Rolandic region is a challenge. Aim of this study is to review a series of patients malignant glioma surgery in the Rolandic region which was performed by combinations of neuronavigation, sonography, 5-aminolevulinic acid fluorescence guided (5-ALA) surgery and intraoperative electrophysiological monitoring (IOM).
Methods: 29 patients suffering malignant gliomas in the motor cortex (17) and sensory cortex (12) were analyzed with respect to functional outcome and grade of resections.
Results: Improvement of motor function was seen in 41.5% one week after surgery, 41.5% were stable, only 17% deteriorated. After three months patients had an improvement of motor function in 56%, of Karnofsky Score (KPS) 27% and sensory function was improved in 8%. Deterioration of motor function was seen in 16%, in sensory function 4% and in KPS 28% after three months. 25% showed no residual tumour in early post surgical contrast enhanced MRI. 10% had less than 2% residual tumour and 15% had 2–5% residual tumour.
Conclusions: Preoperative functional neuroimaging, neuronavigation for planning the surgical approach and resection margins, intraoperative sonography and 5-ALA guided surgery in combination with the application of IOM shows that functional outcome and total to subtotal resection of malignant glioma in the Rolandic region is feasible.

1. Introduction

Only two percent of all cancers are primary brain tumours, but primary malignant brain tumours are among the top 10 of deaths due to cancer [1,2] [http://www.dkfz.de/de/krebsatlas/gesamt/organ.html]. Standard of care in primary malignant brain tumours is a maximally safe resection, followed by radio-chemotherapy [3–5]. Treatment of primary malignant brain tumours is challenging for neurosurgeons especially in so-called eloquent areas. They are not only challenging in decision making to achieve the best strategy for the individual patient but also in surgical handling. Tumour resection leads to histological diagnosis and improves frequently neurological symptoms caused by mass effects or local impairment of functional structures and neurological function. Sometimes seizures can be better controlled after tumour resection. In malignant glioma, grade of resection determines further prognosis as demonstrated before [3]. On the other side life expectancy of these patients is limited and therefore surgery induced longer-lasting new neurological deficits are devastating.

One of the eloquent brain areas is the Rolandic area including the gyrus precentralis also known as primary motor cortex and the gyrus postcentralis with the primary sensory cortex. Tumours in this area often are symptomatic by motor weakness, seizures or disturbance of coordination. Surgery in this area considerable poses a significant risk of paresis, resulting in impairment of life quality.

Only few literature concerning with surgery in the Rolandic region is available. Often authors performed surgery awake to

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preserve motor function [6–8]. The objective of this study is to critically review a series of patients with surgery in the Rolandic area with respect to functional outcome under consideration of presurgical planning, intraoperative monitoring and postoperative outcome in general anaesthesia. Opportunities and also limitations are discussed.

2. Patients and methods

2.1. Patients data

In this retrospective clinical investigation we analyzed clinical data under special consideration of functional outcome, extent of resection (EOR) and intraoperative electrophysiological monitoring (IOM) in patients tumour surgery was performed in the Rolandic region. Before and within 1 week after surgery neurological examination was performed evaluating existing and new neurological deficits. Follow-up examinations were performed in first postoperative week, and every 3 months thereafter. Progression-free survival was defined as the time to tumour progression after surgery as diagnosed on follow-up magnetic resonance imaging (MRI).

We studied 29 patients with primary malignant brain tumours in the pre- and/or postcentral gyrus, in 17 patients the tumours were localized in the precentral gyrus, the other 12 tumours in the postcentral gyrus. From the 29 patients suffered 21 patients of a primary WHO grade IV glioma (glioblastoma), 4 of a recurrent glioblastoma, 2 patients had a recurrent anaplastic oligodendroglioma, 1 patient had a recurrent pineal gland tumour WHO grade III and 1 patient had an atypical neurocytoma.

2.2. Intraoperative monitoring

Intraoperative monitoring (IOM) included tracking of motor evoked potentials (MEP) and somatosensory evoked potentials (SEP) and was described by our group previously [9]. MEPs were continuously recorded using transcranial electro-stimulation via corkscrew electrodes positioned at C-1 and C-3 or C-3 and C-4 for stimulation with high-frequency trains of 5 to 7 pulses at 2-ms intervals corresponding to 500 Hz. Stimulations were always contralaterally applied to the affected side using 350–600 V with 50 μs between stimuli. In most cases stimulation was applied ~1 to 2 times/min. MEPs were recorded from needles placed in the affected target muscles. Baseline values for SEPs and MEPs were acquired before craniotomy. Cortical and subcortical stimulations were performed to localize functional areas and cortical tracts surrounding the lesions. These stimulations were applied using a bipolar probe with the tips 5 mm apart. Pulses for cortical and subcortical stimulations were rectangular, and the current was biphasic with a frequency of 60 Hz. The intensity of the current ranged from 1 to 6 mA, with every stimulation lasting 2 s. Resection was stopped when a functional area or a cortical tract was identified even if tumour tissue was still visible in that area. Moreover, in cases of a permanent decrease in MEP amplitudes acquired from transcranial electrostimulation of >50% compared with the baseline, resection was stopped also.

2.3. 5-Aminolevulinic acid (5-ALA) fluorescence guided surgery

Patients orally received 5-ALA (20 mg/kg bodyweight), which had been diluted in tap water. All surgeries were performed microsurgically using minimally invasive craniotomies. We used an OPMI Pentero microscope (Carl Zeiss) equipped with a fluorescence kit, including a violet-blue excitation light during the fluorescence-guided tumour resections. Microsurgical removal was started using standard white xenon light and switched to the violet-blue excitation light whenever tumour borders were difficult to differentiate from healthy brain tissue. Especially at the end of a resection, the cavity was systematically inspected in the violet-blue light mode to identify any residual tumour.

2.3.1. MRI imaging

Preoperative and postoperative imaging included T1-weighted 3D magnetization-prepared rapid gradient echo (MPRAGE) MR imaging with and without contrast enhancement as well as T2-weighted sequences to visualize edema. Diffusion tensor and functional MR imaging were performed to visualize functional cortical areas and cerebral fiber tracts as reported previously [10,11].

2.3.2. MRI volumetry

Preoperative imaging included gadolinium-enhanced and non-enhanced axial T1-weighted spin echo images with section thickness between 1 and 4 mm depending on the protocol of the referring hospital. In case of insufficient imaging MRI was repeated in our hospital on a 1.5T system (Siemens Sonata or Avanto; Siemens Medical Systems, Erlangen, Germany). An early postoperative MR imaging was performed on the same scanners within 2 days after surgery. Tumour volumes were measured using image fusion and volumetric software (BrainLab iPlan Cranial 2.6; BrainLab AG, Feldkirchen, Germany). For this purpose tumour contours were manually segmented on sequential axial images. The sum of tumour contour surfaces of the MRI study was multiplied by slice thickness to obtain the estimated volume in cm^3. This method has been demonstrated to be reproducible [12–14]. In this way, preoperative tumour volumes were determined on the gadolinium-enhanced T1-weighted images. The residual tumour after resection was determined on gadolinium-enhanced T1-weighted sequences and compared to T1-weighted images without gadolinium for postoperative artifacts. Percentual residual tumour was calculated and categorized in 0%, <2%, 2–5% and >5%.

2.4. Intraoperative sonography

Sonography was performed by the Acuson Antares System 5.0. For tumour visualization we used an ultrasonic sound head VF13-5SP (13–5 MHz) (Siemens AG, Health care, Erlangen, Germany).

3. Results

An overview for the total of 29 patients is given in Table 1. 20 out of 29 patients suffering from malignant gliomas were operated with electrophysiological monitoring, reasons for stopping resection and residual tumour was characterized in more detail, see Tables 2 and 3.

Improvement of motor function was seen in 41.5% of patients, improvement of sensory function in 10.5% and improvement of KPS in 27% of the patients (Fig. 1) one week after surgery. Deterioration of motor function was seen in 17%, in sensory function 3.5% deterioration was detected. The KPS worsened in only 14% of patients. Motor function was stable in 41.5% of patients, sensory function in 86% and the KPS remained stable in 59% of patients.

After 3 months improvement of the motor function showed 56% of the patients and the KPS improved in 32% of the patients. Motor function was stable in 28%, the KPS in 40%. A deterioration of motor function was seen only in 16% of patients, KPS worsened in 28%. The sensory function was stable in 88% (Fig. 1).

Residual tumour was determined by MRI 24 h after surgery with and without contrast agent. Residual tumour was categorized by the relation of contrast enhancing tissue compared to presurgical MRI scans 0%, <2%, 2–5% and >5%. 25% showed no residual tumour. 10% of the patients had less than 2% residual tumour, between 2