Magnetic Resonance Imaging 31 (2013) 923–929

Contents lists available at SciVerse ScienceDirect

Magnetic Resonance Imaging

journal homepage: www.mrijournal.com

The role of intraoperative magnetic resonance imaging in complex meningioma surgery☆

Jehuda Soleman *, Ali-Reza Fathi, Serge Marbacher, Javier Fandino

Department of Neurosurgery, Kantonsspital Aarau, 5001 Aarau, Switzerland

ARTICLE INFO

Article history:
Received 9 August 2012
Revised 3 December 2012
Accepted 24 December 2012

Keywords:
iMRI
Magnetic resonance imaging
Intraoperative imaging
Complex meningioma
Meningioma
Extra-axial tumor

ABSTRACT

Intraoperative magnetic resonance imaging (iMRI) has gained importance in the treatment of gliomas and sellar tumors. In intracranial meningiomas, the extent of surgical tumor removal is one of the most important factors in the prevention of tumor recurrence and patient survival. Complex meningiomas located at the skull base or near eloquent brain regions show higher recurrence rates, morbidity and mortality. The aim of this study was to evaluate whether iMRI contributes to more extensive surgical resection in these tumors. Patients undergoing complex meningioma resection using iMRI from January 2007 to January 2011 were included in this study. The indication for iMRI-guided tumor resection included patients presenting with meningiomas located in the skull base or compressing eloquent brain areas in whom a radical resection was considered to be difficult. Intraoperative 0.15-T MRI scan (PoleStar; Medtronic Navigation, Louisville, CO, USA) was performed before and after maximal possible resection using standard microsurgical and neuronavigation techniques. All patients underwent fluorescence-guided resection. The following data were analyzed: tumor localization, histological grade, Simpson resection grade, duration of the procedure, iMRI scan time, iMRI findings, resection extent based on postresection iMRI, hospitalization time, surgical complications and outcome, and MRI follow-up 2–27 months postoperation. Twenty-seven consecutive patients undergoing complex meningioma resection using iMRI were included. In this series, only one patient (3.4%) underwent resection of tumor remnant after iMRI, although without improvement of the Simpson resection grade. Temporary neurologic deficits were found in 8 patients (27.6%) postoperatively, whereas 11 patients (37.9%) had permanent postoperative neurologic deficits. In one case (3.4%), fatal postoperative bleeding occurred which was not detected by iMRI. Our results show that iMRI has no influence on intraoperative strategy in terms of resection grade or detection of early postoperative complications. The benefits of iMRI in complex meningioma surgery are therefore doubtful; however, it may still prove to be effective in certain subsets of complex meningiomas.

1. Introduction

Meningiomas are the most common benign intracranial tumors, accounting for approximately 20% of all primary intracranial tumors [1–3] (30%–40% in autopsy series [4,5], demonstrating that 10%–20% of meningiomas remain asymptomatic). Incidence peaks at 45 years age, with an annual incidence of 6/100,000 [1] and a female:male ratio of 1.8:1 [3,4]. Multiple tumors appear in 8% of the cases. Ninety percent of all meningiomas are located supratentorially [4], whereas approximately 60%–70% occur along the falx, sphenoid bone and tuberculum sellae or over the convexity [3]. Based on the World Health Organization (WHO) classification, approximately 90% are grade I, 5%–7% are grade II (atypical meningiomas) and 1%–3% are grade III (anaplastic meningiomas) [1,4,6–8]. Treatment of meningiomas is suggested for tumors of initial diameter greater than 25 mm, presence of symptoms, age under 60 years, lack of calcification, hyperintensity on T2-weighted magnetic resonance imaging (MRI) and edema [9,10]. The extent of surgical tumor removal according to the Simpson grading system is one of the most important factors influencing tumor recurrence [3,11].

The resection rate and clinical outcome of patients with complex tumors such as skull base meningiomas have greatly improved with the introduction of microsurgical techniques, ultrasound [12,13], endoscopy [14–23] and 5-aminolevulinic acid (5-ALA) [24,25]. However, radical removal continues to result in high morbidity (33%–76%) and mortality rates (1.4%–4%) [26–30] as compared to the morbidity (4.5%–10%) and mortality (0%–2%) associated with convexity, parasagittal and lateral sphenoid wing meningiomas [31–37].

Whereas intraoperative MRI (iMRI) is an established aid in the surgical treatment of gliomas [38–43] and sellar lesions [44–49] and

---

☆ *E-mail address*: neurosurgery@ksa.ch (c/o Editorial Office Neurosurgery KSA).

* Corresponding author. Tel.: +41 62 838 4141; fax: +41 62 838 6629.

0730-725X/$ – see front matter © 2013 Elsevier Inc. All rights reserved.
http://dx.doi.org/10.1016/j.mri.2012.12.005

in stereotactic tumor biopsy [50], its value in meningioma surgery has not been investigated so far.

The aim of this study was to analyze whether the use of iMRI can lead to a higher rate of tumor resection and improve clinical outcome in complex meningioma surgery.

2. Methods

2.1. Patient characteristics

Data were retrospectively collected and analyzed between January 2007 and January 2011 for all patients consecutively undergoing resection of complex intracranial meningiomas with the aid of iMRI. Complex meningiomas were defined as meningiomas compressing eloquent brain regions or vascular structures, or for which the achievement of a Simpson grade I resection was unlikely. In these cases, iMRI was indicated. The study was approved by the Institutional Review Board of the Kantonsspital Aarau, Switzerland. Written informed consent was obtained preoperatively from all patients or family members. Demographic data were retrospectively collected from patients' charts in addition to the following parameters: tumor localization, histological grade, Simpson resection grade, duration of the procedure, iMRI scan time, iMRI findings, hospitalization time, surgical complications and outcome, and postoperative MRI results. Preoperative radiological assessment included contrast-enhanced MRI scanning and computed tomography (CT) scan to assess bony invasion.

2.2. Operative techniques

Procedures were performed using standard microsurgical (OPMI Pentero; Carl Zeiss AG, Oberkochen, Germany), neuronavigation (StealthStation Treon; Medtronic Navigation, Louisville, CO, USA) and neuromonitoring techniques. In addition, 5-ALA was orally administered 3–5 h prior to skin incision (20 mg/kg; Medac GmbH, Wedel, Germany) to all patients after written consent and confirmation of normal liver transaminases [51]. Intraoperative 440-nm fluorescence was applied periodically during and at the end of resection in order to detect remnants. The PoleStar N20 system (Medtronic Navigation, Louisville, CO, USA) was used for iMRI with a permanent magnet that delivers a 0.15-T magnetic field according to standard protocols. A radiofrequency shield (StarShield) was installed during the scanning sequences. All anesthesiology and surgical equipment was MRI compatible; incompatible instruments were removed prior to the scanning procedure. The patient's head was fixed in an MRI-compatible head clamp, and a radiofrequency coil was attached to the head. Before the patient was draped, a 24-s e-steady sequence [slice thickness, 8 mm; field of view (FOV), 200 mm; repetition time (TR), 40 ms; echo time (TE), 3.3 ms] was performed to test accuracy of the scanning position. Subsequently, an 11-min Gadolinium-enhanced, T1-weighted scan (slice thickness, 2 mm; FOV, 200 mm; TR, 100 ms; TE, 3.3 ms) was carried out for baseline measurements and used for intraoperative navigation. After maximal resection, a subsequent 11-min Gadolinium-enhanced, T1-weighted scan (slice thickness, 2 mm; FOV, 200 mm; TR, 100 ms; TE, 3.3 ms) was obtained. The decision to resect the tumor remnant was based on the iMRI findings after the first resection attempt.

3. Results

3.1. Patient characteristics

A total of 27 patients [14.6%; 29 procedures (15.7%)] out of 185 diagnosed with meningiomas underwent tumor resection with the aid of iMRI. The mean age was 55 years (± 14.8 years, range 31–82 years), with 20 (74.1%) females and 7 (25.9%) males. The patients' clinical characteristics are presented in Table 1. The distribution of tumor location in this series was as follows: the medial/lateral sphenoid ridge ($n=10$, 37%), frontobasal ($n=5$, 18.5%; $n=1$ olfactory groove, $n=2$ with ethmoidal and $n=2$ with infraorbital invasion), cerebellopontine angle, tuberculum sellae, petroclival, tentorial (each $n=2$, 7.4%), sinus cavernosus, convexity, falx and cerebellum (each $n=1$, 3.7%). Indication for iMRI in the latter three cases was compression of essential brain structures or infiltration of sinus, cranial nerves or brainstem. Histological grading was WHO grade I in 21 patients (77.8%), WHO grade II in 4 patients (14.8%) and WHO grade III in 1 patient (3.7%), whereas 1 patient presented with a hemangiopericytoma with WHO grade II. In one (3.4%) case (case 21), the histological examination documented an anaplastic transformation of the tumor (WHO III). Nine cases (31.1%) were reoperations (after 46.4 ± 53.2 months; range 12–156 months) due to new neurologic deficits with ($n=5$, 55.6%) or without ($n=1$, 11.1%) growth of tumor remnant and due to tumor recurrence (3, 33.3%). The mean hospitalization time was 15 days (± 6.26 days, range 8–37 days).

3.2. Intraoperative findings

In 5 cases (17.2%) the achieved Simpson resection grade was I; in 12 cases (41.4%), it was grade II; and in the remaining 12 cases (41.4%), it was grade IV. The mean duration of the procedure was 449.3 min (± 29.6 min, range 265–780 min), whereas the pre- and postresection iMRI mean scan times were 22.5 min (± 8.209 min, range 15–40 min) and 18.5 min (± 5.642 min, range 15–30 min), respectively. In two cases (6.9%; 15 and 27), no postoperative iMRI was carried out due to technical problems. Based on the iMRI findings, tumor remnant was observed in 13 cases (48.1%), whereas in 14 cases (51.9%), no tumor was detected. Extended resection was carried out in one patient (3.8%, case 21), and in one patient (3.8%, case 14), further surgical exploration was performed without any further resection following postresection iMRI. The extent of Simpson resection grade was not influenced in either case (case 21, Simpson grade IV; case 14, Simpson grade II; Fig. 1).

3.3. Postoperative radiological findings

In 17 cases (68%), the postoperative MRI showed tumor remnant; in 7 cases (28%), it showed no suspicion of tumor, whereas in 3 cases (12%), dural enhancement, suggesting either tumor remnant or signal alteration due to gliosis, was observed. Two out of 12 patients with tumor remnant had radio- and/or chemotherapy. The iMRI results correlated in 18 cases (72%) with the postoperative MRI scans. In four cases (13.8%), no comparison was available either because iMRI was not completed after resection due to technical problems (cases 15 and 27), because no postoperative MRI scan was obtained (case 14) or because the patient had already died before a postoperative MRI scan could be obtained (case 26a). A preoperative CT scan was conducted in 26 cases (89.7%), whereas in 9 cases (34.6%), bone alteration (e.g., hyperostosis, hypervascularization), invasion or destruction was seen. A postoperative CT scan was obtained in 20 cases (69%), mostly (70%) due to postoperative complications and the need to assess the bony structures after reconstruction done by dentofacial surgeons. In four cases (20%), the indication for a postoperative CT was unknown; in two cases (10%), a CT scan was initiated since no iMRI was performed. Assessment of bone alteration, invasion or destruction compared to the preoperative CT scan was possible in six cases (66.7%); the remaining three patients did not undergo a postoperative CT scan. In two patients (33.3%), bone alteration, invasion or destruction was observed postoperatively.