Original Investigation

Comparison of Diffusion Tensor Imaging and Magnetic Resonance Perfusion Imaging in Differentiating Recurrent Brain Neoplasm From Radiation Necrosis

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Rationale and Objectives: To compare differences in diffusion tensor imaging (DTI) and dynamic susceptibility-weighted contrast-enhanced (DSC) magnetic resonance (MR) perfusion imaging characteristics of recurrent neoplasm and radiation necrosis in patients with brain tumors previously treated with radiotherapy with or without surgery and chemotherapy.

Materials and Methods: Patients with a history of brain neoplasm previously treated with radiotherapy with or without chemotherapy and surgery who developed a new enhancing lesion on posttreatment surveillance MRI were enrolled. DSC perfusion MRI and DTI were performed. Region of interest cursors were manually drawn in the contrast-enhancing lesions, in the perilesional white matter edema, and in the contralateral normal-appearing frontal lobe white matter. DTI and DSC perfusion MR indices were compared in recurrent tumor versus radiation necrosis.

Results: Twenty-two patients with 24 lesions were included. Sixteen (67%) lesions were placed into the recurrent neoplasm group and eight (33%) lesions were placed into the radiation necrosis group using biopsy results as the gold standard in all but three patients. Mean apparent diffusion coefficient values, mean parallel eigenvalues, and mean perpendicular eigenvalues in the contrast-enhancing lesion were significantly lower, and relative cerebral blood volume was significantly higher for the recurrent neoplasm group compared to the radiation necrosis group ($P < 0.01$, $P = 0.03$, $P < 0.01$, and $P < 0.01$, respectively).

Conclusions: The combined assessment of DTI and DSC MR perfusion properties of new contrast-enhancing lesions is helpful in distinguishing recurrent neoplasm from radiation necrosis in patients with a history of brain neoplasm previously treated with radiotherapy with or without surgery and chemotherapy.

Key Words: Magnetic resonance perfusion imaging; diffusion tensor imaging; radiation necrosis; brain tumor; brain neoplasm.

INTRODUCTION

Conventional magnetic resonance imaging (MRI) is not reliable in distinguishing radiation necrosis from recurrent brain neoplasm in patients with brain tumors previously treated with radiation therapy and surgery (1–4). Stereotactic biopsy and resection remain the most reliable methods for the classification of enhancing lesions that develop in the posttreatment period (2). In recent years, dynamic susceptibility-weighted contrast-enhanced (DSC) MR perfusion imaging and diffusion tensor imaging (DTI) have been used to evaluate posttreatment brain tumor patients. Multiple studies have shown significantly higher relative cerebral blood volume (rCBV) in the contrast-enhancing lesions of patients with recurrent tumor compared to those of patients with radiation necrosis (4–10). Whereas some studies have shown enhancing lesion apparent diffusion coefficient (ADC) values or ratios to be lower in recurrent neoplasms as opposed to radiation necrosis (7,9–13), other studies have shown contradictory findings (14,15). Few studies have published findings specifically examining the DTI characteristics (fractional anisotropy [FA], eigenvalues) of these lesions (7,11–14).

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Our study prospectively analyzes both DSC MR perfusion and DTI characteristics of new enhancing lesions in patients with brain tumors previously treated with radiation therapy with or without surgery and chemotherapy.

MATERIALS AND METHODS

Institutional review board approval was obtained for this prospective cohort study. Informed consent was obtained from all subjects.

Subjects

The study population consisted of 22 subjects with 24 enhancing lesions (mean age: 51 years, range: 18–78 years; eight women [mean age: 58 years, range: 34–78 years]; 14 men [mean age: 47 years, range: 18–69 years]) with a history of treated primary or secondary brain neoplasm who developed a new enhancing lesion on conventional MRI in the posttreatment period. Enrollment of patients occurred between January 2007 and August 2014. Inclusion criteria were (1) a history of histologically confirmed brain neoplasm treated with radiation therapy (including radiosurgery) with or without surgery, (2) the development of a new contrast-enhancing lesion with a size of 1 cm or more on conventional brain MRI after treatment, and (3) an age 18 years or older. Exclusion criteria were (1) pregnancy, (2) an inability to undergo MRI, and (3) the presence of metallic or ferromagnetic prostheses that would obscure imaging results or cause significant artifact. Frequency of conventional MRI examinations for identification of potential study candidates was at the discretion of the clinical service. All screening examinations were standard hospital protocol. Patient demographics are detailed in Table 1. Two subjects, each with two distinct enhancing lesions occurring at separate time points, were enrolled in the study twice.

Original tumor histology was confirmed by pathology report or by clinic note. Nine (41%) of the tumors were glioblastoma multiforme (GBM), four (18%) were oligodendroglioma, one (5%) was anaplastic glioma, three (14%) were astrocytoma, two (9%) were mixed oligoastrocytic neoplasm, and three (14%) were metastatic tumor (two lung and one breast primary tumors). Nineteen (86%) of the subjects were treated with an initial surgical approach, one subject (5%) was treated with chemotherapy and radiotherapy alone, and two subjects (9%) were treated by stereotactic radiosurgery alone. All tumors undergoing initial resection were completely removed. Patients undergoing fractionated radiotherapy received an average radiation dose of 63.6 gray (range: 54–81 gray) for treatment of their index brain neoplasm. Mean interval time between initial brain tumor diagnosis and development of an enhancing lesion on MRI was 2.2 years (range: 0.3–5.6 years) excluding four outlier patients with interval times greater than 10 years.

TABLE 1. Patient Demographics

Patient No.	Sex	Age	Primary Tumor	Diagnosis	Time to Lesion Detection
1	Male	18	Diffuse astrocytoma	Tumor	42
2	Female	57	Metastatic breast cancer	Tumor	51
3	Male	41	Mixed glioma	Tumor	61
4	Male	42	GBM	Necrosis	14
5	Male	20	GBM	Tumor	10
6	Male*	28	Anaplastic glioma	Necrosis/Tumor	14, 28
7	Male	48	Anaplastic astrocytoma	Necrosis	11
8	Male	43	Metastatic lung cancer	Necrosis	41
9	Male	63	GBM	Tumor	12
10	Male	51	GBM	Tumor	18
11	Male	54	GBM	Necrosis	4
12	Male	69	Metastatic lung cancer	Tumor	8
13	Female	62	GBM	Tumor	17
14	Male*	62	Anaplastic oligodendroglioma	Necrosis/Tumor	173, 210
15	Male	68	Anaplastic oligodendroglioma	Tumor	395
16	Male	56	GBM	Tumor	23
17	Female	56	GBM	Necrosis	15
18	Female	51	Anaplastic astrocytoma	Tumor	68
19	Female	60	Mixed glioma	Tumor	8
20	Female	66	Oligodendroglioma	Tumor	146
21	Female	34	Anaplastic oligodendroglioma	Tumor	37
22	Female	78	GBM	Necrosis	50

GBM, glioblastoma multiforme; Necrosis, radiation necrosis; Tumor, recurrent tumor.

* Patient included in study twice for two distinct lesions. Time to lesion detection is defined as time lapse (in months) from initial diagnosis of brain tumor to the development of a new enhancing lesion.