Evaluation of the Intraspinal Enhancement for Medulloblastoma on MR Imaging

Hwa-Young Kim, M.D., In-One Kim, M.D., Woo Sun Kim, M.D., Jung-Eun Cheon, M.D., Kyung Mo Yeon, M.D.

Purpose: The purpose of this study was to analyze the enhancement pattern of the spinal cord for patients with medulloblastoma, and to correlate the enhancement pattern with cerebrospinal fluid (CSF) tumor seeding.

Materials and Methods: We retrospectively reviewed 84 MR images, including the initial and follow-up studies after chemotherapy or radiation therapy, of 25 patients with medulloblastoma who were aged from 2 to 13 years. We analyzed the spinal leptomeningeal enhancement pattern on the MR images. The leptomeningeal enhancement patterns were categorized into three types: Type I, fine or discontinuous linear enhancement, and type II, continuous linear or nodular enhancement, and type III, intradural mass formation. We correlated the enhancement pattern on MRI with the results of CSF cytology at the initial and follow-up examinations after treatment.

Results: Of total 25 patients, type I enhancement was observed for 14 patients. Twelve patients were negative on the initial CSF cytology and 2 patients were positive. On the follow-up MR studies, 14 patients showed no change or only a slight decrease of enhancement, and all were negative on the follow-up CSF cytology. Type II enhancement patterns were observed in seven patients, and all of them were positive on the initial CSF cytology. On follow-up MR study, one patient revealed an increased enhancement with the positive result on the follow-up CSF cytology, and six patients had decreased enhancement on the follow-up MR studies with negative conversion on the follow-up CSF cytology. Type III enhancement patterns were observed in four patients and all of them were positive on the initial CSF cytology. All four patients with intradural mass formations revealed progression of the lesions on follow-up MR studies, and all of them were positive on the follow-up CSF cytology.

Conclusion: Type II and III enhancement patterns always represented CSF seeding and a type I enhancement pattern had a low probability of metastasis.

Index words: Brain neoplasms
Brain neoplasms, metabolism
Brain, MR
Spine, MR

1Department of Radiology and Institute of Radiation Medicine, MRC Seoul National University College of Medicine
Received October 23, 2003; Accepted September 14, 2004
Address reprint requests to: In-One Kim, M.D., Department of Radiology, Seoul National University Children’s Hospital,
28 Yongon-dong, Chongno-gu, Seoul 110-744, Korea.
Tel. 82-2-760-3608 Fax. 82-2-747-5781
There are a variety of brain tumors that may seed into the CSF, and the presence of subarachnoid seeding by neoplasms implies a poor prognosis [1]. Medulloblastoma occurs in the posterior fossa of children and it most frequently metastasizes through the leptomeningeal route. Although CSF cytology has been established as the definitive traditional means for detecting leptomeningeal tumor, a non-invasive imaging modality that can accurately diagnose the subarachnoid spread of primary intracranial neoplasms would be beneficial to clinicians for staging the disease, prescribing treatment and determining the prognosis. The evaluation of the CSF seeding in brain and spine with post-contrast MR imaging has been studied since the late 1980’s, along with the use of myelography and CT-myelography, and the pre- and post-enhanced CT scans have also been regarded as useful methods [2, 3]. The evaluation of CSF seeding on the initial and follow-up studies for the early detection of tumor metastasis is important for therapeutic planning and because of the high rate of recurrence of intracranial lesions.

We retrospectively analyzed the spinal leptomeningeal enhancement patterns for patients with medulloblastoma at initial and follow-up MR studies, and we correlated these findings with the CSF cytologic results for the intraspinal metastasis.

Materials and Methods

We selected 25 consecutive patients with medulloblastoma that was confirmed by operation from January in 1990 to December in 2000, and the patients included 19 boys and 6 girls. The age of patients ranged from 2 to 13 years old (mean, 6.8 years old). All patients underwent suboccipital craniectomy and C1 laminectomy for mass excision, and they received combined chemotherapy and radiotherapy, except for one patient who was less than 3 years old.

A total 84 MR imaging studies (an average of 3.4 times per patient) were performed for the whole spine. We retrospectively analyzed the spinal MR images that were taken during the initial studies and during the follow-up studies after the operations for all patients. The initial MR examinations were performed about 1-2 weeks after the operation in all patients. The follow-up studies that were done during or after chemo or radiation treatment were repeated two to nine times at 4 to 48 months (mean: 19 months) with a 4-6 month interval. Routine imaging sequences were the sagittal T1 weighted image (TR/TE 600-800/12-14 msec, slice thickness; 3-4 mm contiguous sections through the whole spine), and the axial T1 weighted image (TR/TE 600-800/12-14 msec, slice thickness 7-10 mm). The same sequences were used after 0.1 mM/Kg of Gd-DTPA was injected for contrast enhancement. The MR imaging findings after contrast enhancement were categorized into 3 types by the pattern of leptomeningeal enhancement. Type I was fine or discontinuous linear enhancement, type II was continuous linear or nodular enhancement, and type III was intradural mass formation. The criteria for the thickness of the enhanced leptomeninges used for dividing the patterns into type I and type II imaging findings was the thickness of the peripheral nerve roots on post-contrast axial scan.

CSF cytology examinations for these patients were performed within a day after MR examination. We compared the MR enhancement pattern with the result of

![Fig. 1. A 2-year-old boy with medulloblastoma. The initial MR image shows fine discontinuous leptomeningeal enhancement, a finding which finding was classified as type I, along the surface of the spinal cord in the lower thoracic spine and upper lumbar spine levels on post-contrast T1 sagittal scan (arrows). The follow-up MR image shows slightly decreased enhancement (not shown). No malignant cells were found at the initial and follow up CSF cytology examination.](image-url)
CSF cytology. We analyzed the changes of the enhancement pattern on MR and the result of CSF cytology at the follow-up studies.

**Results**

At the initial MR examinations, the enhancement patterns in spinal cord were analyzed as follows; 14 patients had type I, seven patients had type II and four patients had type III. Twelve of 14 patients with type I enhancement patterns exhibited negative CSF cytology and two patients revealed positive cytology (Fig. 1). We could not find any difference in the MR findings between the negative and positive cytology results. The enhanced segments with type I enhancement patterns were mainly located from the lower thoracic spine to the upper lumbar spinal levels. All patients with type II (Fig. 2) and type III (Fig. 3) enhancement patterns were positive on the initial CSF cytology.

On the follow-up MR studies, seven of 14 patients with type I enhancement patterns showed no interval changes, and the remaining seven patients revealed mild decreases in the extent of enhancement. All patients with type I enhancement patterns were negative on the follow-up CSF cytology. One of seven patients with type II enhancement patterns showed progression of the extent of lesion on the follow-up MR imaging, and they were still positive on the follow-up CSF cytology. Six of seven patients with type II enhancement patterns showed decreases in the extent of enhancement of the lesions on the follow-up MR imaging, and they revealed negative conversion of the CSF cytology. Four patients with type III enhancement patterns revealed progression of lesions on the follow-up MR images. One patient with type III enhancement patterns showed temporary regression of lesions at the 4 month follow-up MR imaging, but the intradural masses recurred with aggravation on the 13 months follow-up MR imaging. CSF cytology results in patients with type III enhancement patterns were positive at the follow-up studies.

**Discussion**

Metastatic spread of disease in the spinal subarachnoid space may originate from neoplasms arising from within the central nervous system such as cerebral glioblastoma, ependymoma, medulloblastoma and non-CNS tumor (2). Medulloblastoma is the most frequently

---

Fig. 2. A 5-year-old boy with medulloblastoma.

A. The initial post-contrast T1-weighted image shows nodular and linear enhancement (arrows) on the surface of the spinal cord (type II). CSF cytology examination revealed positive results for malignant cells.

B. The axial image shows continuous round rim enhancement (arrow) around the spinal cord. The enhanced segment is thicker than the enhanced peripheral nerve root.

C. The follow-up image shows decreased leptomeningeal enhancement (arrows). CSF cytology revealed negative conversion.
metastasized tumor in children, and this spreads via the CSF pathway. Leptomeningeal metastasis in medulloblastoma can be identified on the initial imaging studies in 10 to 50% of patients, and it is found as recurrent lesion on follow-up images (3). Although CSF cytology has been the traditional means of diagnosis for leptomeningeal metastasis, non-invasive imaging modalities can accurately diagnose the subarachnoid spread of primary intracranial neoplasms. Post-contrast MR imaging is the superior method for diagnosing subarachnoid dissemination and for monitoring the disease response to therapy due to its high resolution, the relatively short evaluation time and fewer artifacts from this modality, the non-invasiveness of the procedure and there are no serious side effects of intravenous Gd-DTPA (4-7). In children who present with acute hydrocephalus and posterior fossa tumor, the danger of herniation often negates the possibility of lumbar puncture. Post-contrast MR imaging in this clinical situation is useful because of its non-invasive nature and ease of performance (8). In spinal imaging, the sagittal scan is usually used for evaluation of the subarachnoid space. If evidence of intradural extramedullary disease in spine is sought, the T1 weighted sagittal images before and after the enhancement will be sufficient, and an axial scan can be used as a supplement. T2 weighted images may not be necessary (8).

The leptomeningeal enhancement pattern itself could be confusing for determine the stage and extent of disease. Both layers of the pia-arachnoid have tight junctions within the capillaries and therefore, leptomeningeal enhancement is normally not seen or it is subtle following contrast administration for either MR or CT (9, 10). Diffuse or widespread multifocal nodular enhancement and thickened leptomeninges are the typical finding of leptomeningeal metastasis on the post-contrast MR imaging (11, 12). However, this could also represent a non-tumorous condition such as granulomatous infection (13). The fine discontinuous linear enhancement pattern in the leptomeninges of the brain or spine on post-contrast MR has been described as normal (14, 15) or as benign inflammation, such as the patterns that occurs from bacterial meningitis, sarcoidosis or postoperative hemorrhage (16, 17). Sze et al (15) and Watanabe (18) have found that Gd-enhanced MR imaging was normal in nearly one third of cases with clinically diagnosed meningeal carcinomatosis. They suggested that these cases might have been at an early stage, or they were less severely affected, and that as the disease progresses, diffuse or nodular meningeal enhancement could be seen. The median survival time of these patients was, however, longer than the median survival
time of the patients for whom the typical MRI findings of CSF seeding were seen at the initial examination. Our patients with type I enhancement patterns did not experience tumor recurrence during the follow-up period after chemotherapy and radiotherapy, while all the patients with type III enhancement patterns died within four years even though they were small in series.

Traditionally, a definitive diagnosis requires the finding of malignant cells in CSF cytologic examination, and this remains the most accurate means for detecting the leptomeningeal tumor. However, several lumbar punctures may be required to establish the accurate diagnosis [19]. On occasion, the results of the CSF are equivocal despite repeated lumbar punctures because a false negative diagnosis may result from strong adherence of malignant cells to the leptomeninges. Gd-DTPA enhanced MR imaging may serve an adjunctive purpose here [8]. CSF cytology is more frequently positive in patients with diffuse meningeal involvement (>75%) than for those patients with focal disease (38%), and also for those patients with the leptomeningeal enhancement pattern than for those patients with the dural enhancement pattern [20].

In our study, patients with type II and type III enhancement patterns presented with subarachnoid metastasis, but patients with type I enhancement patterns showed metastasis, as proven by CSF cytology, in only 2 of 14 cases (14%), and the remaining 12 cases (86%) were presumed to be benign inflammatory changes due to chemical reactions of the blood after the operations. Common postoperative findings in the meninges vary from no enhancement to smooth dural enhancement, and this may persist for a prolonged period of years [9]. The possibility of a complicating infection after an operation could be ruled out by the clinical signs. The criteria for differentiating between insignificant [i.e. postoperative] and significant [i.e., neoplastic or inflammatory] meningeal enhancement have not been established for the pediatric population [6, 15]. The non-tumorous condition of fine discontinuous enhancement in our cases could be the result of meningeal irritation caused by postoperative blood in the subarachnoid space, but the possibility of metastasis could not be excluded. Therapy after operating, including chemotheraphy and craniospinal radiation, had been performed in our cases and regular follow-up examinations are recommended.

In conclusion, the type I enhancement patterns with a fine discontinuous linear enhancement had a low probability of seeding, while type II and III enhancement patterns always represented CSF seeding. Further studies are necessary to delineate the difference between the tumorous condition and the non-tumorous condition of leptomeningeal enhancement for type I enhancement patterns.

References