Postoperative Meningeal Enhancement on MRI in Children with Brain Neoplasms

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MR imaging with contrast (Gd-DTPA) enhancement has been widely used postoperatively in children with brain neoplasms for the detection of recurrent tumor, metastasis or other complications. It primarily demonstrates the lesions that disrupt the blood-brain barrier (BBB).

The meninges are composed of the dura, the arachnoid and the pia mater. The dura lacks BBB; however intense enhancement does not occur because of its relative avascularity. This explains the variable degree of enhancement of normal dura. Both arachnoid and pia normally do not enhance because of a tight functional BBB despite of their relative vascularity (1, 2).

Physical disruption of the integrity of the meninges from a variety of causes including surgery results in various patterns of meningeal enhancement on contrast enhanced MR images. It is important to distinguish normal reactive or benign postoperative enhancement from more serious leptomeningeal metastasis or infection, particularly in children with intracranial neoplasms. We present various patterns of meningeal enhancement on MRI in children following surgery for brain neoplasms.

Index words : Children, central nervous system
Meninges, MR
Magnetic resonance (MR), contrast enhancement
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We experienced 23 children with various meningeal enhancement on MRI following surgery for brain neoplasms. Among them, seven showed "normal" reactive meningeal enhancement. Sixteen had dural enhancement associated with subdural fluid collection or hemorrhage. Two of these 16 also had clinical evidence of infection, and one had leptomeningeal metastasis.

We present various patterns of meningeal enhancement on MRI in children following surgery for brain neoplasms.
Normal Meningeal Enhancement

Intravenous administration of Gd-DTPA causes enhancement of normal cranial dura. It is seen as a thin, linear, short segmental pattern of enhancement and is most prominent parasagittally (Fig. 1). Mild normal dural enhancement is thought to be due to lack of BBB although the dura is relatively avascular (1, 2, 6). Intravascular enhancement of the meningeal vessels contained in the dura, which supply the inner portion of the calvaria, appears to be another reason for normal dural enhancement (6). Long, thicker or more intense meningeal enhancement suggests abnormality. A normal falx occasionally enhances in a thin uniform pattern.

Postoperative Meningeal Enhancement

Normal Reactive Enhancement

A variety of patterns can be seen in postoperatively well children from no enhancement to smooth thin dural enhancement (Figs. 2, 3). It could be localized seg-

Fig. 1. Normal meningeal enhancement.
Enhanced T1-weighted coronal MR image shows thin, discontinuous pattern of linear dural enhancement (arrows) and enhancement along the falx (arrowhead). Calvarial marrow fat (curved arrows).

Fig. 2. Postoperative normal reactive meningeal enhancement.
Enhanced T1-weighted axial MR image obtained 4 months after surgery demonstrates very thin, short segment of linear dural enhancement over frontal convexities bilaterally (arrows). Large postoperative surgical defect (S) is seen on the right.

Fig. 3. Postoperative normal reactive meningeal enhancement.
Enhanced T1-weighted axial MR image obtained 1 year following surgery shows diffuse, continuous and linear dural enhancement over convexities and along the falx. No postoperative complications such as subdural fluid collection or hemorrhage are seen. The child was clinically well.

Fig. 4. Postoperative benign meningeal enhancement.
Enhanced T1-weighted axial image (A) obtained 1 month after surgery show a localized fluid collection (F) with adjacent dural enhancement (arrows) at the site of operation. Normal postoperative, thin, short segments of linear dural enhancement (short arrows) is seen over convexities bilaterally (B).
mentally or diffuse over the convexities, and may persist for many years following surgery. According to the study by Hudgins et al. (1), the type of surgery or time since surgery did not appear to affect the pattern of meningeal enhancement.

Meningeal enhancement following intracranial surgery is likely due to physical interruption of the BBB, and inflammatory process or chemical arachnoiditis caused by subarachnoid hemorrhage occurring at the time of surgery (1, 4, 6).

**Subdural Fluid Collection/Hemorrhage**

Subdural fluid collection or hemorrhage frequently occurs immediately after surgery (7). The dura adjacent to the fluid collection or hemorrhage is thickened and moderately to markedly enhanced. It could be localized at the operative site (Fig. 4) or diffuse over the convexities, depending on the extent of fluid collection or hemorrhage. The thickness and intensity of dural enhancement appear to increase with time (Fig. 5). As the subdural fluid collection or hemorrhage becomes chronic and organized, numerous capillaries grow inward from the outer aspect of the fluid collection or hematoma, forming a membrane which is relatively vascular. This causes varying degrees of enhancement in the periphery of the fluid collection or hemorrhage (1, Fig. 5). Post-he-
morrhagic inflammation of the meninges may lead to meningeal fibrosis (5).

Infection/Leptomeningeal Metastasis

Pia-subarachnoid space enhancement follows the brain surface, extending into the depths of the sulci (7). Pia-subarachnoid space or ependymal enhancement suggests infectious (Figs. 6, 7) or leptomeningeal metastasis (Fig. 8); it may be focal or diffuse and have either a smooth or nodular contour (8). Irregular or nodular dural enhancement with thickening also indicates a significant pathologic process. A diffuse appearance favors infectious process, while a nodular pattern of enhancement highly suggests leptomeningeal metastasis (7, 8).

Conclusion

A variety of meningeal enhancement is seen postoperatively in children with brain neoplasms on MRI. Mild degree of meningeal enhancement can be seen normally, and mild to moderate enhancement and thickening of the dura are commonly seen associated with postoperative subdural fluid collection or hemorrhage.

Postoperative meningeal enhancement does not necessarily indicate leptomeningeal metastasis or infection.

References


Fig. 8. Malignant meningeal enhancement.
Enhanced T1-weighted MR images (A, B, C) show abnormal ependymal enhancement of the both lateral ventricles and along the floor of the 4th ventricle (arrows) and multiple ependymal nodules (arrowheads) along the ventricular wall, representing extensive tumor dissemination via cerebrospinal fluid (CSF). Bilateral, diffuse dural enhancement over convexities on coronal image (B) is thought to be benign in nature associated with subdural fluid collection (short arrows). On midsagittal image (C), tuber cinereum is abnormally thickened and enhanced (crossed arrow) by tumor dissemination. Irregular enhancement is seen at the margin of operative site in posterior fossa (X). Cerebrospinal fluid (CSF) was positive for malignant cells.
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혈액-뇌장벽 (blood-brain barrier)에 대한 연구는 최근의 생물학적 개념을 바탕으로 연구되고 있다. 이 장벽은 뇌 조직과 혈액 사이에 존재하며, 뇌의 구조와 기능을 유지하는 중요한 역할을 한다. 최근에는 뇌의 질병에 대한 이해와 치료를 위한 연구가 활발하게 진행되고 있다.
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Summer Abdominal Imaging Conference (2000) 7th 3rd-7th
venue: Jackson Hole, Wyoming, Grand Teton Nat. Park, USA.
contact: Janice Ford Benner, Univ. of PA Medical Center, 3400 Spruce Street, 1 Silverstein Bldg., Philadelphia, PA 19104, USA.

Meeting on Risk Management & Error Avoidance in Clinical Radiology (2000) 7th 7th
venue: British Institute of Radiology, London, United Kingdom.
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Congress on the New Advances in Diagnostic Imaging (2000) 7th 8-11th
venue: Rome, Italy.
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22nd Annual Diagnostic Imaging Conference (2000) 7th 10-14th
venue: Harbor View Hotel, Martha's Vineyard, MA, USA.
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Six-Week Radiologic Pathology Course (2000) 7th 17-25th
venue: Washington, DC, USA.
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World Congress on Medical Physics & Biomedical Engineering/42nd Annual Meeting American Association of Physicists in Medicine (2000) 7th 25-30th
venue: Navy Pier, Chicago, IL, USA.
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