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Postoperative Meningeal Enhancement on MRI in Children with Brain Neoplasms[1]

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The meninges composed of the dura, the arachnoid and the pia are significant sites of blood-brain barrier. 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
Neoplasms, in infants and children

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 and shunt placement results in various patterns of reactive and benign meningeal enhancement on contrast enhanced MR images (3, 4, 5). It is important to distinguish normal reactive or benign postoperative enhancement from more serious leptomeningeal metastasis or infection. It is particularly important in children with intracranial neoplasms, because a number of common pediatric tumors such as medulloblastoma, ependymoma, pineal region tumor, or anaplastic astrocytoma have a tendency for leptomeningeal metastasis via the cerebrospinal fluid (CSF) (1).

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.

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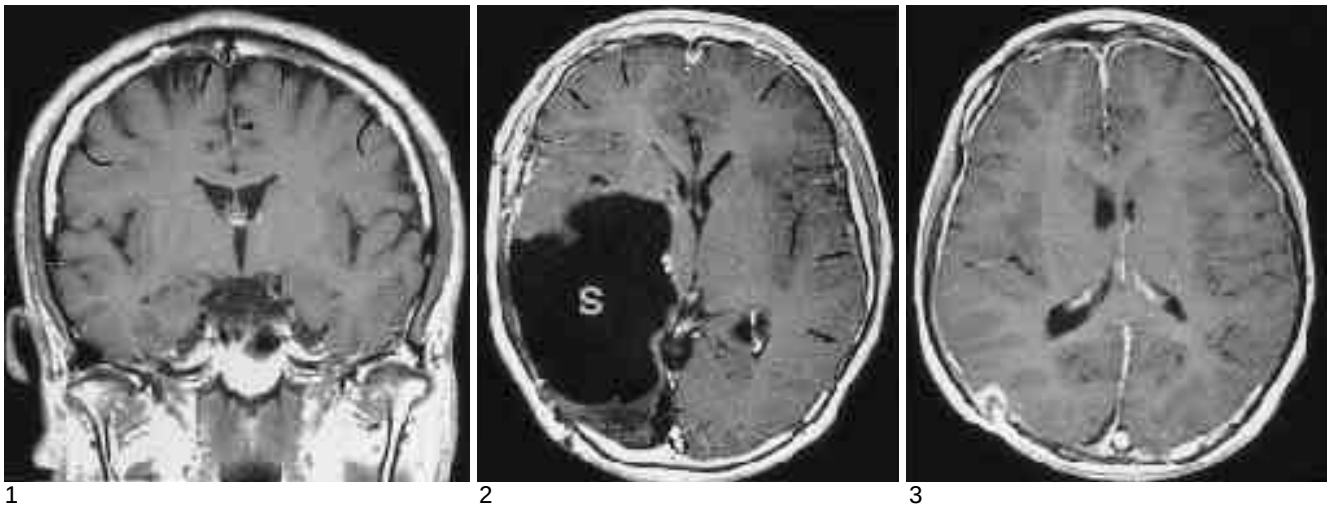
Normal Meningeal Enhancement

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 calvavia, 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-

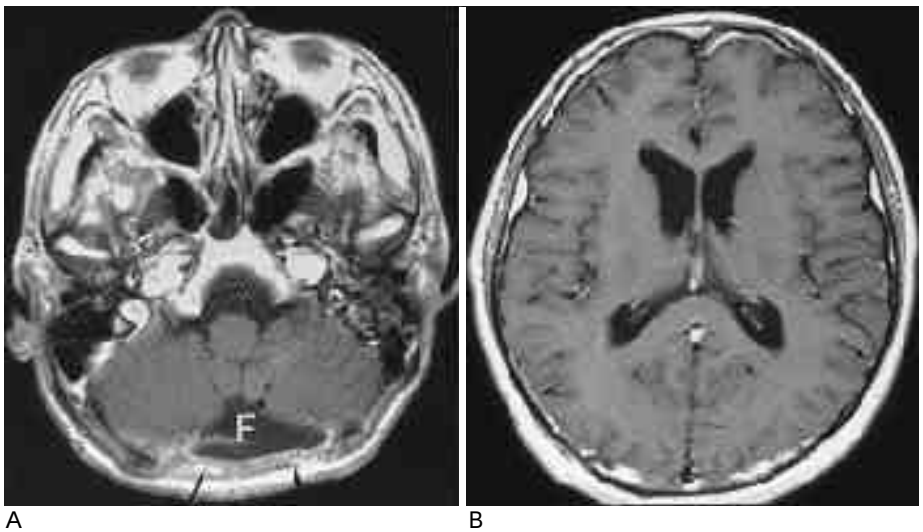


1 2 3

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.



A B

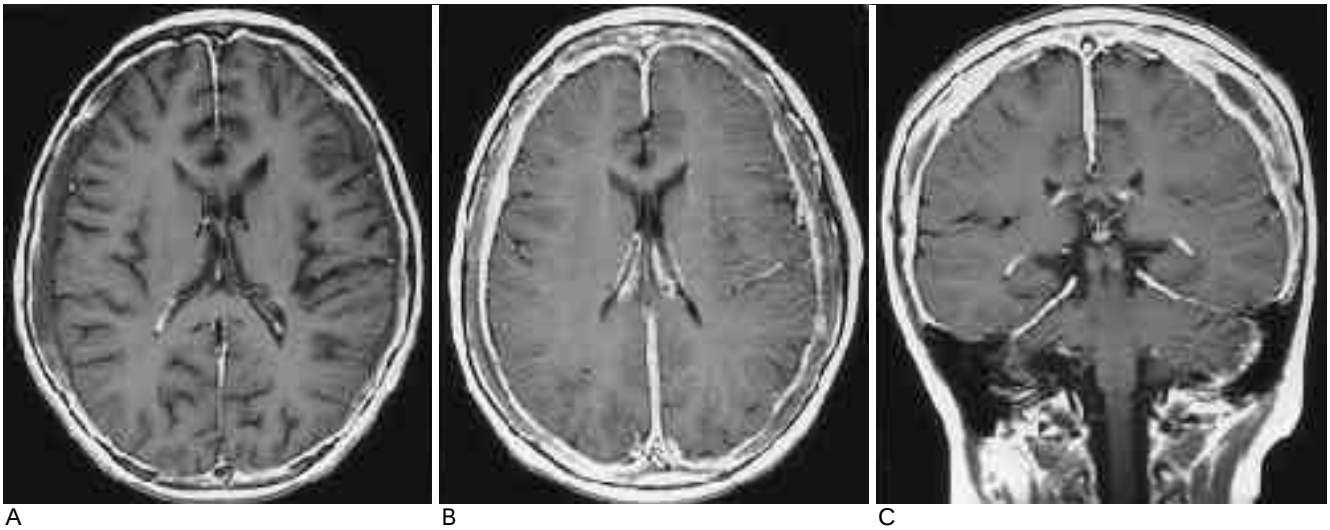
Fig. 4. Postoperative benign meningeal enhancement.
Enhanced T1-weighted axial image (A) obtained 1 month after surgery show a localized fluid collection (F) with adjacent dural enhancement (arrows) at the site of operation. Normal postoperative, thin, short segments of linear dural enhancement (short 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).

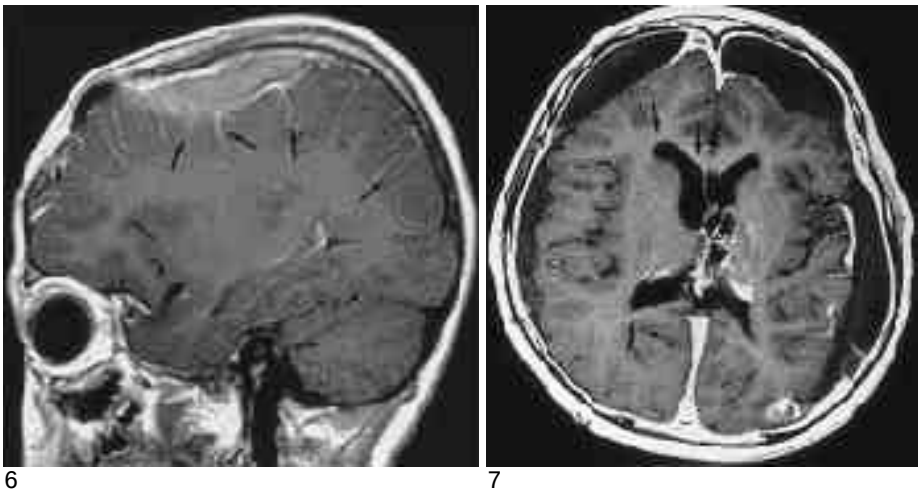
Subdural Fluid Collection/Hemorrhage

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-



A B C

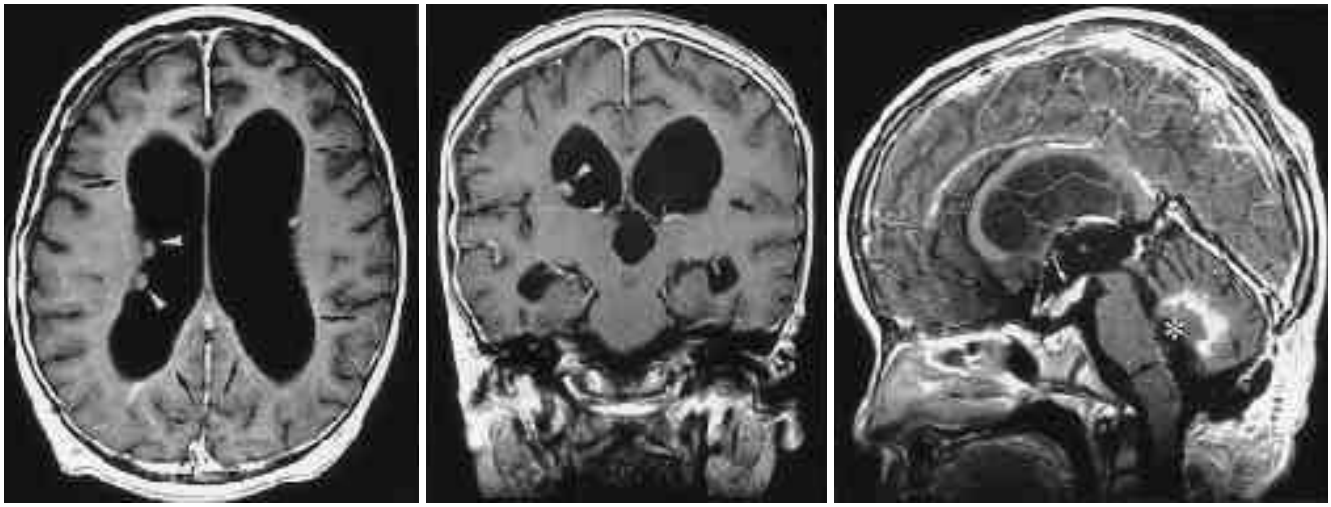
Fig. 5. Postoperative benign meningeal enhancement.
Enhanced T1-weighted axial MR image (A) obtained 2 months following surgery reveals slightly thickened, wavy and generalized dural enhancement along the margin of subdural fluid collections. Enhanced T1-weighted axial (B) and coronal images (C) obtained 1 year later show persistent bilateral subdural fluid collections with increasing dural thickening and enhancement. Irregular peripheral enhancement of the fluid collection is seen, suggesting organizing phase of the fluid collection. The child was clinically well.



6 7

Fig. 6. Infectious meningeal enhancement.
Enhanced T1-weighted sagittal MR image shows abnormal leptomeningeal enhancement (arrows) in the frontal and parietal lobes, extending deep into the brain sulci. Overlying subdural high signal intensity area was proved to be pus mixed with hemorrhage at surgery.

Fig. 7. Infectious meningeal enhancement.
Enhanced T1-weighted axial MR image demonstrates ependymal enhancement of right frontal and occipital horns (arrows). Diffuse dural enhancement and thickening associated with bilateral subdural fluid collections are also seen. Cerebrospinal fluid (CSF) study revealed presence of WBC, and increased protein level, indicating infectious condition. Postsurgical defect (*).



A B C

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 (*). Cerebrospinal fluid (CSF) was positive for malignant cells.

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.

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소아뇌종양수술후 자기공명영상에서 뇌막의 조영증강소견[1]

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이민희 · 김보경 · 윤혜경 · 신형진[2]

경막과 지주막, 그리고 연막으로 구성된 뇌막은 뇌-혈류 장벽(blood-brain barrier)에 중요한 역할을 하는 구조물이다. 수술을 비롯, 여러 원인에 의한 뇌막상태의 손상은 자기공명영상에서 다양한 양상의 조영증강 소견을 초래한다. 뇌수술후 정상적인 반응, 또는, 양성인 뇌막의 조영증강 양상과 연수막을 통한 종양의 전이나 감염에 의한 뇌막의 조영증강 양상을 감별하는 것은 매우 중요하며, 특히 소아뇌종양 환아에서는 더욱 그러하다. 저자들은 뇌종양 수술을 받은 소아의 자기공명영상에서 보이는 뇌막의 다양한 조영증강 양상을 소개하고자 한다.

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■ **CONGRESS ON THE NEW ADVANCES IN DIAGNOSTIC IMAGING (2000년 7월8-11일)**
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E-mail: Pavone@uniromal.it)

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(tel: 1-202-7822272; fax:1-202-7828124;
E-mail: gittleson@afip.osd.mil)

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