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Curved Planar Reconstruction of MR Images in Focal Cortical Dysplasia of the Brain[1]

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Purpose: To describe curved planar reconstruction imaging (CPRI) and determine its usefulness in the evaluation of focal cortical dysplasia of the brain.

Materials and Methods: In 17 cases of focal cortical dysplasia [cortical dysplasia ($n=9$), schizencephaly ($n=5$), and heterotopia ($n=3$)], CPR images were created using a multiplanar reconstruction program and imaging data obtained during T1 magnetization-prepared rapid acquisition gradient-echo MR imaging. We assessed the precise configuration of abnormalities and their relation to adjacent gyri and sulci.

Results: CPRI showed the brain cortex as a 2D panoramic image, demonstrating the precise configurations and locations of dysplasia-associated abnormalities and their relation to adjacent gyri and sulci, and the precise shape of the gray-white matter interface.

Conclusion: CPRI can provide important radiological information about the extension and configuration of focal cortical dysplasia, and its relation to neighboring cortical structures. We believe that CPRI should form an essential part of the routine investigation of suspected cases of focal cortical dysplasia.

Index words : Brain, abnormalities
Seizures
Brain, MR

Focal cortical dysplasia is a potent epileptic focus responsible for intractable seizures (1 - 3), and because the focal nature of these lesions makes them amenable to surgical therapy there is intense interest in their diagnosis (2, 4, 6).

Prior to surgery, it is very important to know the precise location and shape of the lesion that causes the seizures, and a detailed knowledge of the topographical relationship between these lesions and the cortical regions responsible for motor functions and speech is essential.

Notable technical developments, including advances in instrumentation and faster pulse sequences, have led to increased sensitivity in the detection of minor structural abnormalities confined to the cortex (7 - 13). However, mild dysplasia characterized only by cortical disorganization is still not always detected (7, 8, 14 - 17), and for the evaluation of cortical dysplasia, curved planar reconstruction imaging (CPRI) of the brain cortex using data acquired with three-dimensional (3D) MR techniques may be helpful (18, 19). In several of our

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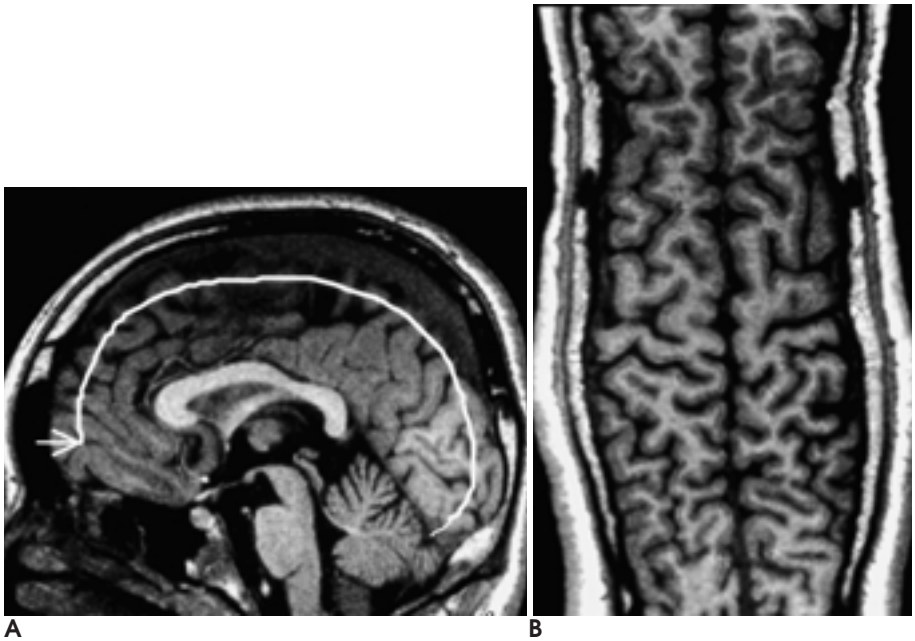


Fig. 1. Curved planar reconstruction image of a normal volunteer.
A. Sagittal MP-RAGE image shows curved reconstruction plane.
B. Curved reconstruction image shows the brain cortex as a 2D in a panoramic like view.

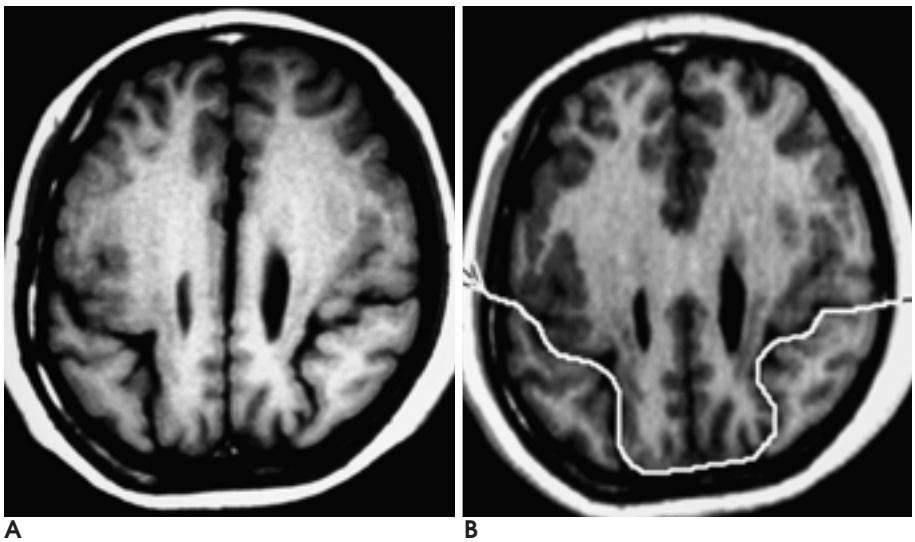
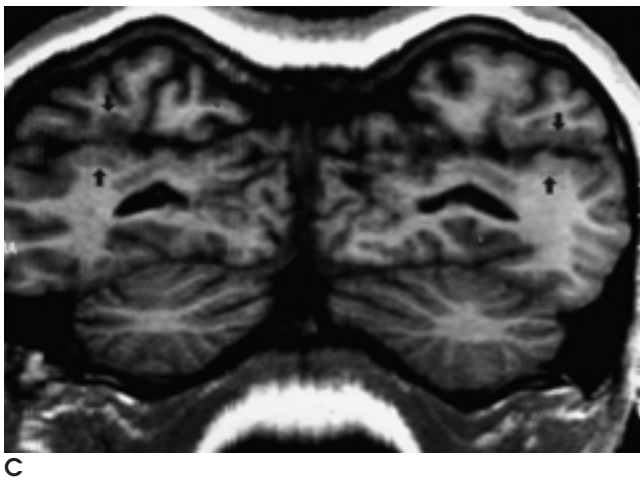


Fig. 2. A 21-year-old female with bilateral parieto-occipital polymicrogyria.
A. Axial T1-weighted image.
B. Curved cuts reconstruction line.
C. Curved planar reconstruction image. The cortical clefts are visible in the axial image (**A**), but the full extent of the broad based, thickened dysplastic cortex is better depicted in both occipital areas (arrows) (**C**).



epileptic patients in whom a preoperative survey was undertaken, this method provided topographic delineation of lesions, demonstrating their relation to adjacent gyri and sulci.

Materials and Methods

In 17 patients with focal cortical dysplasia [cortical dysplasia ($n=9$), schizencephaly ($n=5$), heterotopia ($n=3$)], CPR images were created from MR imaging data. Among six patients who underwent surgery, MR diagnoses of cortical dysplasia and schizencephaly were histologically confirmed in four and two cases, respectively. The eleven remaining patients were diagnosed

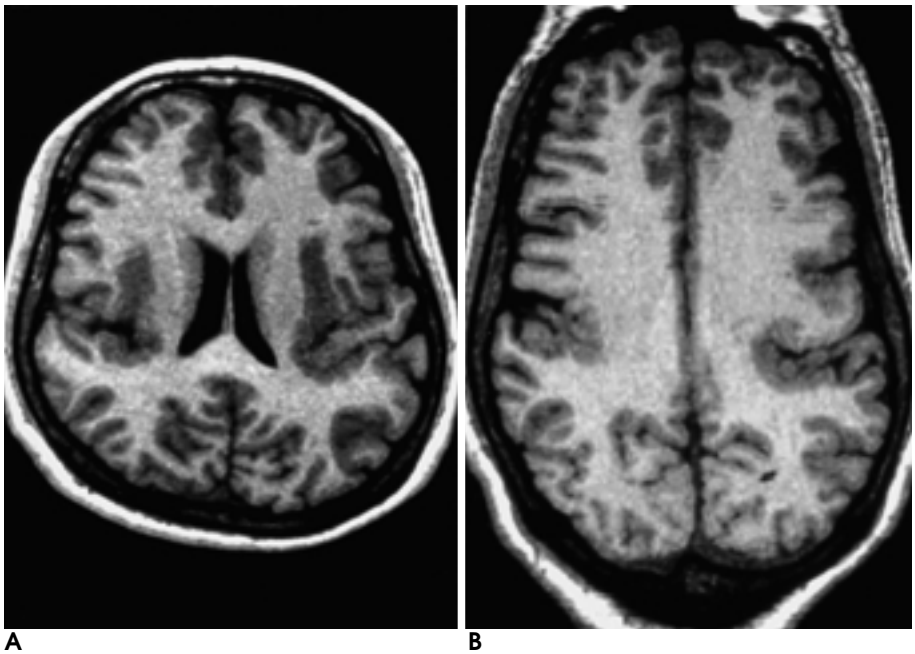


Fig. 3. A 41-year-old female with bilateral perisylvian syndrome.
A. Axial T1-weighted image shows thickened gray matter in the bilateral perisylvian areas and left parietal cortex.
B, C. Curved planar reconstruction images show the size and shape of the cortical abnormality in both perisylvian areas. The gyri and sulci surrounding both sylvian fissures appear to have abnormal configurations.

on the basis of typical MR imaging findings.

For all examinations, a 1.5-T Vision system (Siemens, Erlangen, Germany) was employed, and a three-dimensional image set was obtained using a T1 magnetization-prepared rapid acquisition gradient-echo (MP-RAGE) sequence. The imaging parameters were 9.7/4/1 msec (repetition time/echo time/excitations), with a 12 ° flip angle and an inversion time of 300 msec. The coronal slab was 256 mm thick, with 256 partitions, yielding a partition thickness of 1 mm. A 256×256 mm field of view was used with a 256×256 matrix to obtain in-plane resolution of 1×1 mm. Image acquisition time was 11 minutes 54 seconds.

CPR images were created using the Curved Cuts Multi-Planar Reconstruction program (Vision; Siemens, Erlangen, Germany). The MRI data of each patient were first submitted to visual analysis, using conventional reformatting in the orthogonal planes. For subsequent CPR imaging, lines which followed the curvature of the brain were drawn in the parasagittal, coronal, and lateral planes, guided by areas deemed suspicious at initial screening and according to clinical-EEG data. The program reformats the available data, providing CPR images along the defined reconstruction line and perpendicular to the reference image (Figs. 1A, 2B). The time lapse between drawing a line in the brain image plane, and the acquisition of one CPR image, was approximately two seconds. As far as possible, reformatting included the visualization of homologous corresponding areas in both hemispheres, and several different views were obtained.

Working independently, two radiologists performed masked reading of a set of CPR images and a set of routine MR images. Their 3-point visibility score (CPRI and routine MRI equally clear; CPRI clearer than routine MRI; CPRI much clearer than routine MRI) was used to assess the precise configuration of abnormalities and their relation to adjacent gyri and sulci.

Results

CPRI showed the brain cortex as a 2D panoramic image (Figs. 1B, 2C).

Among the 17 patients, lesions were much clearer at CPRI than at routine MRI in 14 cases (82%) according to

observer 1, and in 13 cases (76%) according to observer 2. Lesions were equally clear in three cases (18%) (observer 1) and four cases (24%) (observer 2); three such lesions, they agreed, were heterotopic.

CPRI demonstrated the precise configurations and locations of the cortical abnormalities occurring in focal cortical dysplasia, the precise shape of the gray and white matter interface, and the relation of the abnormalities to adjacent gyri and sulci, as shown in Figs. 2 - 7.

The first conventional analysis of MRI in one patient with cortical dysplasia revealed an area of dysplastic cortical thickening in the right perisylvian region. CPRI, though, provided better visualization of dysplastic cortical configurations (Fig. 4).

In one patient with schizencephaly, an additional cortical lesion was missed at conventional MRI. CPRI

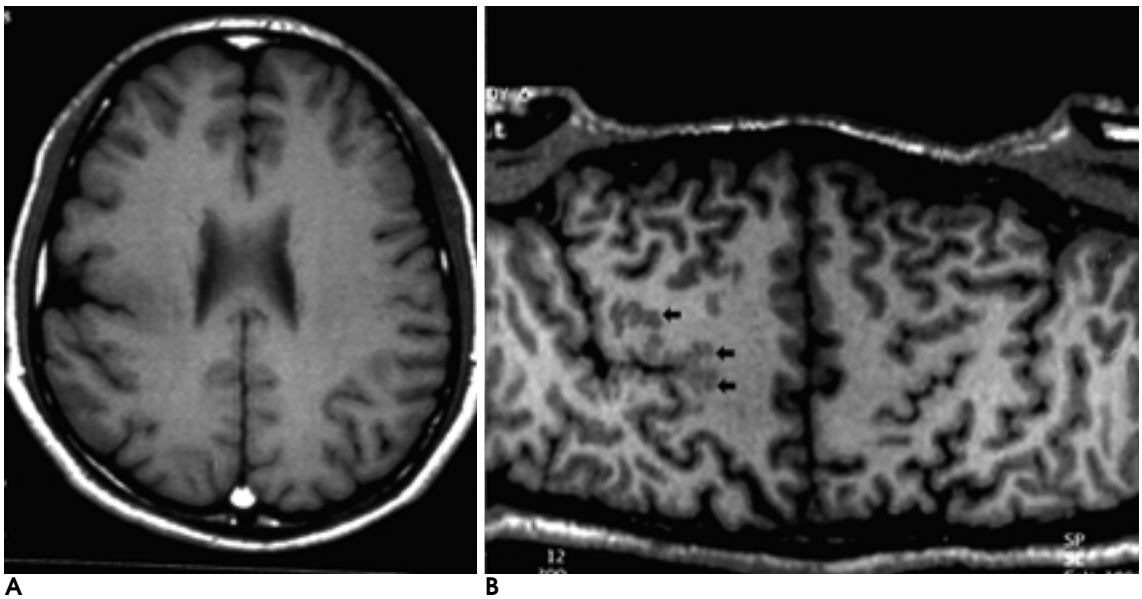


Fig. 4. A 42-year-old male with right perisylvian cortical dysplasia.
A. Axial T1-weighted image shows thickened gray matter in the right perisylvian area.
B. Curved planar reconstruction image shows better visualization of nodular thickening of cortical configurations and irregular cortical gray-white matter junction (arrows).

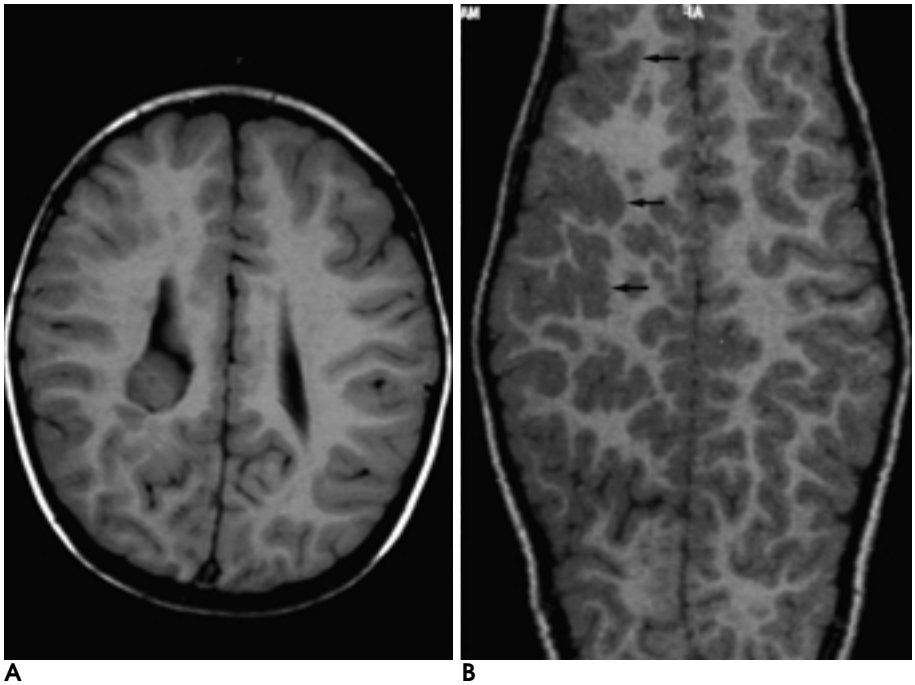


Fig. 5. A 34-year-old male with closed lip schizencephaly.
A. Axial T-1weighted image.
B. Curved planar reconstruction image. Axial image (**A**) shows gray matter in ependymal surface of the right ventricle. Curved planar reconstruction image (**B**) shows associated cortical thickening in the right frontoparietal area (arrows).

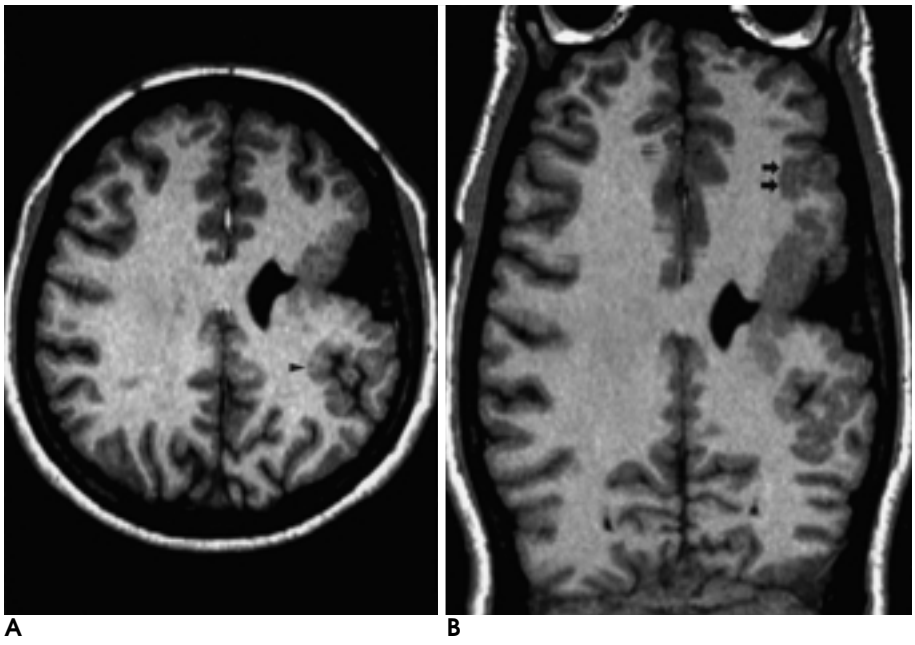


Fig. 6. A 22-year-old female with closed lip schizencephaly.
A. Axial T1-weighted image.
B. Curved planar reconstruction image.
Axial image (**A**) shows gray matter-lined cerebrospinal fluid-filled cleft that extends from the ependymal surface of the brain through the white matter to the pia with polymicrogyria in the left cerebral hemisphere. Associated cortical dysplasia is revealed in the left parietal cortex (arrowhead). Curved planar reconstruction image (**B**) shows gray matter-lined cleft, parietal cortical dysplasia, and associated cortical dysplasia in the left frontal cortex (arrows).

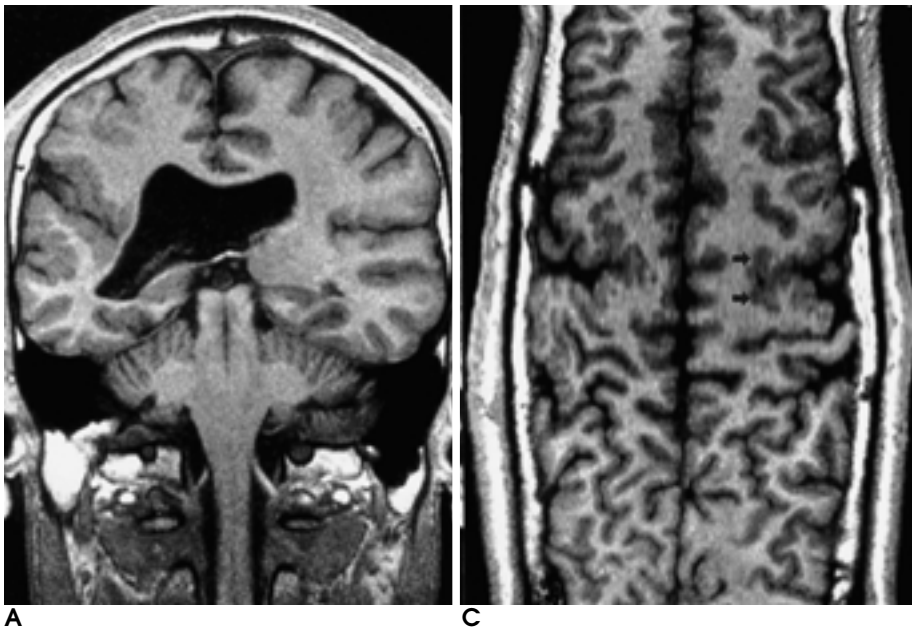
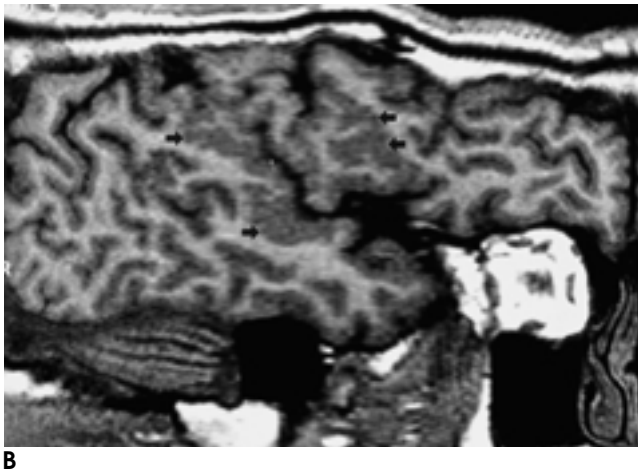


Fig. 7. A 28-year-old male with closed lip schizencephaly.
A. Coronal T1-weighted image.
B, C. Curved planar reconstruction images.
Coronal image (**A**) shows gray matter-lined cleft with thick polymicrogyria in the right cerebral hemisphere. Curved planar reconstruction image (**B**) shows thick, irregular, and bumpy gray matter involving the right sylvian fissure (arrows). Curved planar reconstruction image (**C**) demonstrates associated cortical dysplasia in the left sylvian fissure area (arrows).



demonstrated abnormal cortical thickening in the right frontoparietal region, and irregularity at the cortical gray-white matter junction (Fig. 5).

In two patients with schizencephaly, CPRI provided better definition of two additional areas of focal cortical dysplasia revealed by conventional orthogonal MR imaging (Figs. 6, 7).

Discussion

In the assessment of cortical abnormalities, CPRI was superior to visualization in conventional planes, permit-

ting symmetric visualization of the cortical ribbon and of gray-white matter transition throughout the cerebral convexity, as well as valid comparison between homologous areas.

The success of CPRI depends on the quality of the MR imaging sequence. Our choice of 3D MP-RAGE acquisition was based on the findings of a previous study, in which it demonstrated excellent spatial definition and good T1-weighted contrast while maintaining short imaging times (11 - 13, 20). The ability to reconstruct a 3D data set into any desired plane merely by drawing a line in that data set may decrease the need for repeat imaging, and might eventually help shorten patient scan time. Using this technique, we obtained various serial curved slices along the hemispheric convexities, rendering 2D images of the cortical structure at different depths. An advantage of CPR images is that to obtain them from 3D-reconstructed images takes only a few seconds. Moreover, they can be displayed directly on Siemens MR operating screens without the need for a special graphic workstation. Another advantage of the curved reconstruction technique is the concurrent visualization of both hemispheres, permitting the direct detection of any gyral asymmetry.

CPRI along a nerve can clearly delineate its size and shape along its entire course; along the anterior optic pathway it can improve visibility of the optic nerves and chiasm, and facilitate comparison between the two nerves (21). CPRI is particularly well suited to visualization of the retrobulbar periscopic buckling of the optic nerve caused by its elongation; along the hippocampus it can display the " circuit of Papez ", which cannot be displayed by normal planar acquisition or 3D reconstruction (22).

The detection and precise localization of cortical abnormalities in patients with drug-resistant extratemporal epilepsy are important in surgical decision-making, particularly in those with abnormalities closely related to eloquent areas such as the sensorimotor gyri. The CPRI technique is such that to provide insight into the relationship between a lesion and the pre- and postcentral gyri, Broca 's area, and Wernicke 's area, guiding the neurosurgeon and helping to limit postoperative neurological deficits, several reconstructions are essential.

Focal cortical dysplasia is characterized by the abnormal arrangement of neurons and glia in focal areas of the cerebrum. MR images in patients with focal cortical dysplasia demonstrate, for example, abnormal signal intensity in the white matter, blurring of the gray-white matter junction, and nodular or band-like cortical thickening (1, 3, 6 - 10, 14 - 17). Meencke and Veith (23) found that 46.5% of 591 brains of epileptic patients had migration abnormalities. In MRI-negative cases, several authors have demonstrated the presence of cortical dysplasia neuropathologically (7, 8, 15 - 17); thin contiguous slices and multiplanar reformatting applied to MRI improved the detection of the subtle abnormalities present in such cases (24). CPRI improved the visibility of the precise configuration and location of focal cortical dysplasia, and its relation to adjacent gyri and sulci. The deep border of the cortical gray matter adjacent to the white matter was visible on 2D images, but the relationship between gray and white matter and the precise shape of lesions were revealed most clearly by CPRI.

The term " schizencephaly " refers to full-thickness clefts present within the cerebral hemispheres, and the condition is readily diagnosed at conventional 2D MR imaging, which also depicts the abnormal cortex flanking and lining the cleft. Schizencephaly is often associated with cortical dysplasia in other parts of the brain cortex (25 - 26). CPRI delineates the precise shape and location of dysplastic cortex lining the cleft, the relationship between the lesion and adjacent sulci and gyri, and associated cortical dysplasia in other areas of the brain. Although 2D images delineate quite successfully the relationship between schizencephaly clefts and the central sulcus, they do not provide a comprehensive view. CPRI not only demonstrates the precise relationship and extent of the lesion, but also reveals configurations of both the cleft and the gyri and sulci adjacent to the lesion.

The most obvious advantage of CPRI is its ability to display the precise gray-white matter interface and to depict abnormal cortical thickening, abnormal gyral patterns, and the anatomical relationships of surrounding structures. Our observations have indicated that the routine use of CPRI may be useful, not only by adding information and clarifying the nature of suspicious areas detected on conventional slices, but also in detecting subtle cortical lesions that could be missed at conventional examination.

In conclusion, CPRI can provide important radiological and anatomical information about the extent and configuration of focal cortical dysplasia and its relation to neighboring cortical structures. We believe that CPRI should be part of the routine investigation of suspected cases of focal cortical dysplasia.

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국소적 뇌피질 이형성증의 곡면재구성영상[1]

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목적: 3차원 MR영상법으로 촬영된 MR데이터를 사용하여 곡면재구성영상을 얻어 국소적 뇌피질 이형성증을 평가하는데 유용성을 알아 보았다.

대상과 방법: 국소적 뇌피질 이형성증 17명을 대상으로 하였고 뇌피질 이형성증(cortical dysplasia, *n*=9), 분열뇌증(schizencephaly, *n*=5), 이소성 회질증(gray matter heterotopias, *n*=3)이었다. 곡면재구성영상은 자화준비고속경사에코획득을 이용하여 얻은 영상에서 곡면재구성프로그램을 이용하여 만들었다. 곡면재구성영상에서 병변의 범위, 모양, 주위 정상 대뇌이랑, 고랑과의 관련성을 분석하였다.

결과: 곡면재구성영상은 뇌표면을 파노라믹 모양의 2차원으로 벌려 놓은 모양이었다.
17예의 국소적 뇌피질 이형성증 환자에서 곡면재구성영상은 이형성된 뇌피질의 위치와 모양, 그리고 주위의 정상 대뇌이랑과 고랑과의 관계를 잘 보여 주었다.

결론: 곡면재구성영상은 국소적 뇌피질 이형성증 환자에서 병변의 위치와 범위 그리고 주위 구조물사이의 중요한 방사선과적 그리고 해부학적 정보를 제공했다. 국소적 뇌피질 이형성증이 의심될 때 곡면재구성영상은 일반적인 영상방법과 함께 포함되어야 할 검사법이다.