Magnetic Resonance Imaging of the Brain in Epileptic Pediatric Patients: Review of the Experience in Ramathibodi Hospital

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Objective : *To review a series of epileptic children referred for MR imaging and correlate the structural abnormalities from the MRI findings with clinical data and EEG..*
Material and Method : *Retrospective review of MRI of the brain performed in children, aged less than 15 years with epilepsy at Ramathibodi Hospital from January 1999 to December 2002 was done. There were 100 children (57 girls, 43 boys) with epilepsy, age range from one month to 14 years, mean 7 years and 5 months. Diagnosis of seizure type and epilepsy were classified according to clinical presentation and EEG..*
Results : *There were 16 children with primary generalized seizure, 79 children with partial or complex partial seizures with or without secondary generalization. The remaining 5 children had a specific syndrome. The most common etiology of all patients was congenital disease, especially cortical dysplasia. Among children with partial with or without generalization, cortical dysplasia was the most common finding (31%). Mesial temporal sclerosis and combined cortical dysplasia with mesial temporal sclerosis were found in 24% and 13.9%, respectively. Most of the disease categories showed significant concordance of the EEG to the MRI findings, except infectious disease.*
Conclusion : *The most common etiology of epilepsy in children under 15 years old was cortical dysplasia. For children with partial or complex partial seizure, cortical dysplasia was the most common etiology followed by mesial temporal sclerosis and combined cortical dysplasia with mesial temporal sclerosis, respectively. MRI provides precise etiologic classifications of epilepsy..*

Keywords : *MRI brain, Epileptic pediatric patient, EEG*

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Seizures are the common neurologic disorder in the pediatric age group and occur with frequency of 4-6 cases/1000 children in the United States of America (USA)[1]. A seizure is defined as paroxysmal involuntary disturbance of brain function that may be manifested as an impairment or loss of consciousness, abnormal motor activity, behavioral abnormalities, sensory disturbance, or autonomic dysfunction. Epilepsy is defined as recurrent seizures unrelated to fever or to an acute cerebral insult. An epileptic seizure is a clinical manifestation of abnormal, excessive neuronal activity arising in the gray matter of the cerebral cortex[2]. Idiopathic epilepsy is diagnosed in most children due to undetermined etiology of seizure[1,3,4].

The electroclinical expression of epilepsy depends on several factors, including the presence of subjacent brain anomaly and the age of the child[1]. Genetic, congenital and perinatal disorders account for most of the cases[1].

Although the outcome for most uncomplicated seizures in children is good, a small number have persistent seizures refractory to drugs, and these pose a diagnostic and management challenge[5-7]. Recently, there are many investigations and modalities available for diagnosis and searching for the cause of the seizure, such as electroencephalography (EEG),

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magnetic resonance imaging (MRI), and single-photon emission computed tomography (SPECT), as well as positron emission tomography (PET)[8-10].

MRI can be used to identify the structural abnormality of the brain in order to understand the condition and, in selected case, used for treatment planning such as surgery[11,12].

The purpose of this study was to review a series of epileptic children referred for MR imaging of the brain at Ramathibodi Hospital to detect structural abnormalities and to describe and analyze the MRI findings in correlation with the clinical data and EEG.

Material and Method

The MRI study and MRI reports of all children, aged under 15 years who presented with epilepsy or seizure and underwent MRI study for investigation at Ramathibodi Hospital from the 1st January 1999 to 31st 2002, were searched from the entire database in the Radiology Department and retrospectively reviewed. There were 150 children. Twenty-nine children were excluded from this study due to incomplete clinical data. There were 21 children without evidence of seizure or epilepsy from the clinical review.

There were 100 children included in this review. Fifty-seven were girls and 43 were boys. Their ages ranged from one month to 14 years (mean 7 years 5 months, SD 4 year 6 months). The age distribution is shown in Table 1.

All the studies were reviewed by a board certified neuroradiologist or radiologist countersigned by a board certified a neuroradiologist. The diagnosis of seizure types and epilepsy were classified by a pediatric neurologist, according to the clinical presentation and the EEG.

For MRI study, all cases were studied by using a 1.5 Tesla superconductive magnet and NVi/CVi, (Signa General Electric Medical system, Milwaukee, USA) with gradient strength of 10 and 40 mT/sec, respectively, using the protocol shown in Table 2.

Table 1. Patients data with age distribution

Age groups	No.	%
0 to 1	13	13
>1 to 5	22	22
>5 to 10	37	37
>10 to 15	28	28
Total	100	100

Inclusion criteria

1. All children under 15 years old who presented with epilepsy or seizure and had MRI studies at Ramathibodi Hospital from 1st January 1999 to 31st December 2002.

Exclusion criteria

1. The patients with unavailable MRI studies and incomplete clinical data.

2. The patients without evidence of seizure or epilepsy from the clinical review.

MRI results were classified into gender, age groups and disease categories as shown in Table 3.

Table 2. MRI protocol for epilepsy

- Sagittal SE T1W (TR/TE/NEX = 460/14/2)
- Axial SE T1W (TR/TE/NEX = 400/14/2), FSE T2W (TR/TE/NEX = 4000/85/3) and FLAIR (TR/TE/NEX = 9000/120/1)
- Diffusion image (B value = 1000, 3000)
- Coronal GRE T2W (TR/TE/NEX = 700/20/2) of the whole brain (5/1.5 mm)
- If Gadolinium administration; axial and coronal SE T1W (TR/TE/NEX = 400/14/2)
- Thin slice obliqued coronal (3 mm/interleave) perpendicular to the hippocampal plane in FLAIR (TR/TE/NEX = 9000/120/2), FSE T2W (TR/TE/NEX = 3000/85/4) and 3D SPGR (TR/TE/NEX = 30/4.2/1) sequences of the whole brain

Table 3. Disease categories

Categories	Diseases
Congenital disease	ie., cortical dysplasia, Sturge-Weber syndrome, other disorders of neuronal migration
Trauma	ie., accident, following elective surgery
Vascular disease	ie., arteriovenous malformations, cerebral venous thrombosis, infarction
Neoplasm	ie., oligodendroglioma
Infection	ie., meningitis, viral encephalitis, cerebral abscess
Mesial temporal sclerosis (MTS)	Mesial temporal sclerosis
Degenerative disease	ie., Alzheimer's disease, other neurodegenerative disease
Idiopathic/Other non-related findings	ie., Normal MRI of the brain, sinusitis, diffuse mild brain atrophy

Statistical analysis

The clinical data were collected as clinical findings and EEG. All data were analyzed for defining the relationship of each data (MRI finding, clinical data and EEG), using statistic methods (i.e., percent of agreement, Kappa analysis and p-value). The outcome was defined as concordance or discordance of the EEG and MRI findings.

Results

MRI findings

MRI findings of all 100 children were categorized into congenital disease, mesial temporal sclerosis, infectious disease, trauma, vascular disorder and tumor. The congenital diseases were composed of cortical dysplasia and developmental anomaly. Encephalitis, meningoencephalitis and cerebritis were defined as infectious diseases. The vascular disorders were arterio-venous malformation (AVM), carotid occlusion, cavernous angioma and Moya moya disease. The MRI findings in selected children are shown in Fig. 1-7.

All 100 children were categorized as described above. There was no child in trauma or degenerative categories. Some children had more than one disease from MRI findings. The details are shown in Table 4.

In almost all age groups, congenital disease was the most common cause of the epilepsy followed by mesial temporal sclerosis. Of the 5-10 years age group, the most common cause was mesial temporal sclerosis. For the children with more than one category found in MRI, there were 15 patients with cortical dysplasia and mesial temporal sclerosis. The rest were developmental anomaly with mesial temporal sclerosis and encephalitis with mesial temporal sclerosis. In 3 cases with tumor, two of them were in the 5-10 years group and the other one was in the 1-5 years age group. Non-related MRI findings were found equally in all age groups, except for the first year of life. The etiologies of epilepsy in each age group are shown in Fig. 8

In 9 children who had non-related MRI findings, only one boy had a normal MRI. A boy with secondary generalized seizure, normal physical exami-

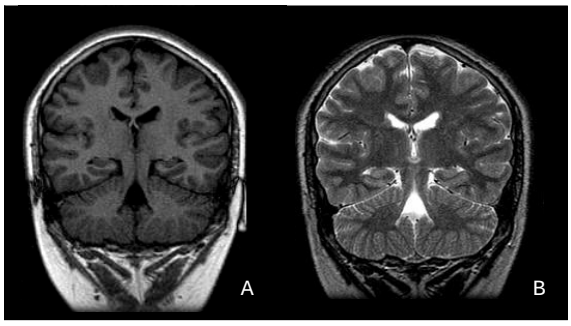


Fig. 1 MRI Coronal IR (A) and T2 (B) of a 13- year-old boy who presented with atonic epilepsy, EEG showed epileptiform discharge. Cortical dysplasia at bilateral temporal and right parietal lobes

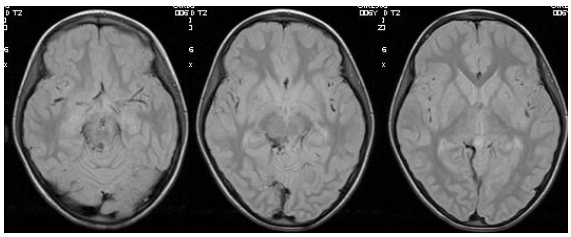


Fig. 2 Axial PD T2 of a 6-year-old girl with localized related epilepsy, EEG showed focal epileptiform discharge. There were multiple tortuous vessels at the right ambient cistern, representing an AVM

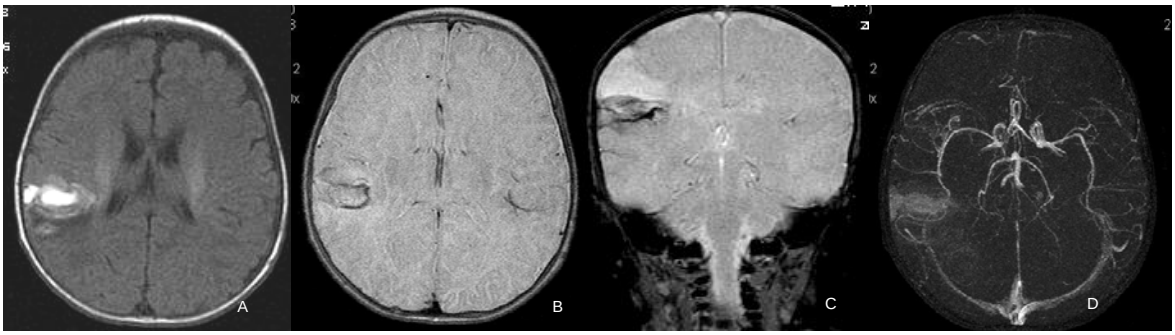


Fig. 3 Axial FLAIR (A), GRE axial (B)and coronal(C). Of a 2-month-old boy, who presented with localized related epilepsy, showed subacute intraparenchymal hematoma at the right inferior parietal gyrus with dilated cortical veins and prominent posterior opercular branches of the right middle cerebral artery. Axial 2D PC MRA (D) showed no definite focal stenosis, aneurysm or A-V shunt. The hemorrhage could be from a small rupture, a cryptic AVM or cavernoma

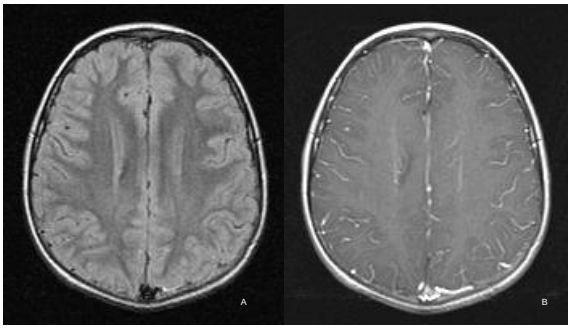


Fig. 4 Axial FLAIR (A) and T1 with Gadolinium (B) of a 6-year-old boy, who presented with secondary generalized epilepsy and normal EEG. There was diffuse cortical edema with markedly increased leptomeningeal and intravascular enhancement at the left superior parietal gyrus, most likely due to viral encephalitis

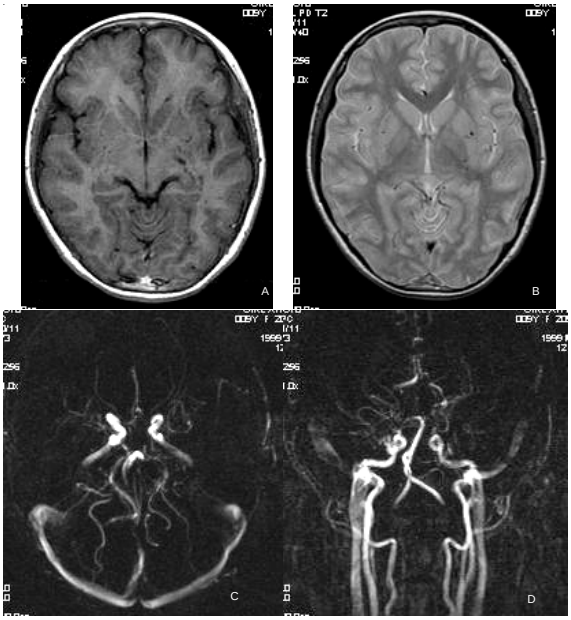


Fig. 5 Axial T1 (A), PD T2 (B) and 2DPC MRA of a 9-year-old girl with simple partial seizure with secondary generalzied tonic clonic seizure, and nonspecific abnormal EEG. Multiple flow void structures along bilateral basal ganglia and corona radiatae were detected (white arrows). MRA (C, D) showed severe stenosis to almost occlusion of bilateral supraclinoid internal carotid arteries with prominent lenticulostriate collaterals (arrow heads), compatible with Moya moya disease

nation and nonspecific abnormal EEG, the MRI revealed only surgical track at the posterior fossa. MRI studies of the other two girls showed nonspecific mildly diffuse brain atrophy, could be the result of long standing seizure, without evidence of mesial temporal

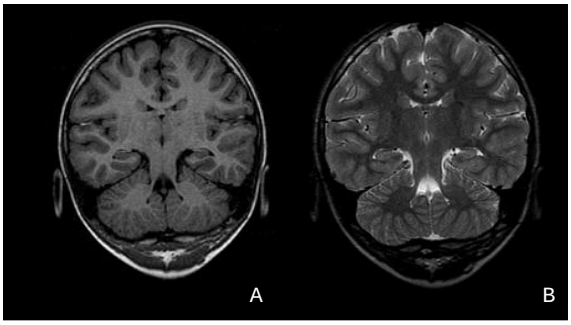


Fig. 6 Coronal IR (A) and T2 (B) of a 9-year-old girl with complex partial seizure, and nonspecific abnormal EEG. Moderate abnormal hyposignal T1/hypersignal T2 change and atrophy of left hippocampus is noted, compatible with hippocampal sclerosis

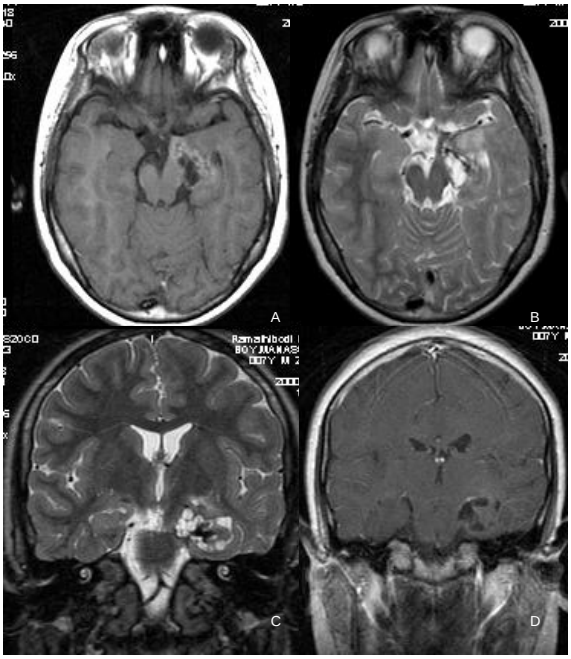
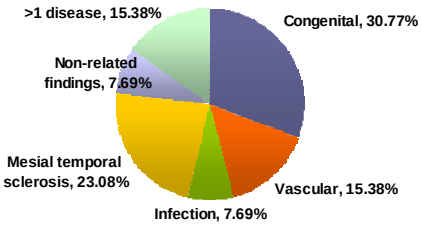


Fig. 7 Axial T1 (A), Axial T2 (B), coronal T1 (C) and T2 (D) of a 7-year and 9 month-old boy with symptomatic localized seizure and normal interictal EEG. Ill-defined minimal enhancing heterogeneous mass with nonenhancing hyposignal T1 and T2 of calcification at the head and body of left hippocampus, compatible with oligodendroglioma

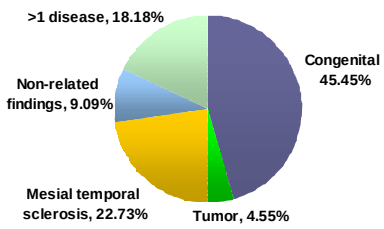
sclerosis. The remaining 5 children had maxillary, ethmoid, and/or sphenoid sinusitis and mastoiditis without intracranial abnormality.

MRI and clinical presentation

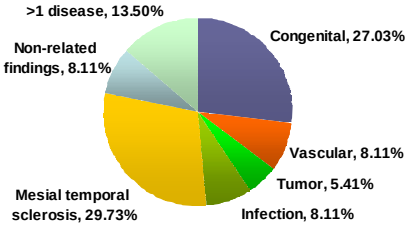
Among 100 children in the present study, 60 of them had generalized seizure and representing the most common type of seizure. They were divided into



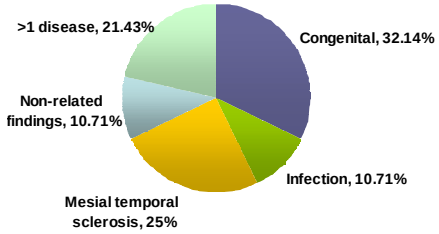
(A) Age 0-1 Yr.



(B) Age 1-5 Yrs.



(C) Age 5-10 Yrs.



(D) Age 10-15 Yrs

Fig. 8 Distribution of the disease categories, according to age group

primary generalized, secondary generalized and idiopathic generalized epilepsy as shown in Table 5.

Of the 35 children with focal epilepsy, they were composed of symptomatic focal, localized related, temporal lobe and frontal lobe epilepsy as shown in Table 6.

The remaining 5 children with special syndromes were Infantile spasms, Lennox-Gastaut syndrome, and Landau-Kleffner syndrome as shown in Table 7.

There were 16 children with primarily generalized seizures and 79 children with either partial or complex partial seizures with or without secondary generalization. The details of clinical presentations of the children are shown in Table 8 and 9.

Among the children with partial with or without generalization, cortical dysplasia was the most common MRI findings, 31.6%. Mesial temporal sclerosis and combined cortical dysplasia with mesial temporal sclerosis were found in 24% and 13.9%, respectively.

Table 4. Disease category classifications

Disease categories (no, %)	No.	%
Congenital disease	34	34
Cortical dysplasia (27, 79.4%)		
Developmental anomaly (7, 21.6%)		
Mesial temporal sclerosis	24	24
Vascular disorders	5	5
Moya moya (2, 40%)		
Cavernous angioma (1, 20%)		
AVM (1, 20%)		
Bilateral carotid occlusion (1, 20%)		
Infection	8	8
Meningoencephalitis (4, 50%)		
Encephalitis (3, 37.5%)		
Cerebritis (1, 12.5%)		
Tumor	3	3
Medulloblastoma (1, 33.3%)		
Oligodendroglioma (1, 33.3%)		
Low grade glioma (1, 33.3)		
More than 1 categories	17	17
Non-related findings	9	9
Total	100	100

Table 5. Details of Generalized epilepsy

Generalized epilepsy	No	%
Primary generalized epilepsy	12	20.00
Secondary generalized epilepsy	44	73.33
Idiopathic generalized epilepsy	4	6.67
Total	60	100

Table 6. Details of Focal epilepsy

Focal epilepsy	No	%
Symptomatic focal epilepsy	4	11.43
Localized related epilepsy	22	62.86
Temporal lobe epilepsy	8	22.86
Frontal lobe epilepsy	1	2.86
Total	35	100

Table 7. Details of Special syndromes

Special syndromes	No	%
Infantile spasms	2	40
Lennox-Gastaut syndrome	2	40
Landau-Kleffner syndrome	1	20
Total	5	100

Table 8. The clinical presentations of each disease

	Cortical dysplasia	Develop-mental anomaly	MTS	MTS+ other	Non-related findings	Tumor	AVM	Caver-noma	Other vascular disease	Infection	Total
Primarily generalized	1	1	4	5	2	0	0	0	1	2	16
Partial	6	2	4	2	3	3	1	1	1	3	26
CPS	4	0	5	0	0	0	0	0	0	0	9
Focal with secondarily	15	3	10	9	4	0	0	0	1	2	44
Infantile spasms	1	0	1	0	0	0	0	0	0	0	2
LGS	0	0	1	1	0	0	0	0	0	0	2
LKS	0	1	0	0	0	0	0	0	0	0	1
Total	27	7	25	17	9	3	1	1	3	7	100

Table 9. Partial and Partial with generalized seizure

	Cortical dysplasia	Develop-mental anomaly	MTS	MTS+ others	Non-related findings	Tumor	AVM	Caver-noma	Other vascular disease	Infection	Total
Partial	6	2	4	2	3	3	1	1	1	3	26
CPS	4	0	5	0	0	0	0	0	0	0	9
Focal with secondarily	15	3	10	9	4	0	0	0	1	2	44
Total	25	5	19	11	7	3	1	1	2	5	79
%	31.6	6.3	24.1	13.9	8.9	3.8	1.3	1.3	2.5	6.3	100

Cortical dysplasia, mesial temporal sclerosis and combined cortical dysplasia with mesial temporal sclerosis were the most common findings in children with partial or complex partial seizures in our study.

MRI and EEG

The locations of abnormalities from the MRI findings and the EEG were compared, using Kappa analysis for the agreement. Suggested citation for this software was StataCorp. 2003. Stata Statistical Software: Release 8.0 college Station, Tx: Stata corporation. The details of each disease category are shown in Table 10.

Most of the MRI findings were concordant with the EEG with statistical significance ($p < 0.05$), except the infectious category ($p > 0.05$).

In the tumor category, all three cases showed the same locations in MRI and the EEG, but the sample size was too small to be calculated for statistical significance.

Discussion

In the present study, the MRI study, the clinical data, and EEG were collected and analyzed. The most common clinically diagnosed seizure type was generalized seizure. The congenital disease,

Table 10. MRI versus EEG

	Expected agreement	Kappa	P value
Cortical dysplasia	21.70%	0.255	0.0042
Developmental anomaly	48.98%	0.72	0.0073
Mesial temporal sclerosis	29.51%	0.4089	0.0005
Infection	21.88%	0.04	0.3667
Vascular disorder	43.75%	0.5556	0.0409
Dysplasia+MTS	46.53%	0.2208	0.0104
Tumor	Cannot be evaluated		

especially cortical dysplasia was the most common MRI finding in children with all type of seizures.

For the infant and young children (0-5 years) age group, the authors found that congenital disease was the most common cause of the epilepsy followed by mesial temporal sclerosis, similar to the study of Annergers JF[9] which showed developmental anomalies was the most common cause in this group. In the group of older children (5-15 years) the authors found congenital disease was again the most common cause of epilepsy, whereas the study of Annergers JF[9] showed an increased incidence of infection.

Also, noted cortical dysplasia and combined cortical dysplasia with mesial temporal sclerosis were the most common findings in children with partial or complex partial seizures. According to the presence of abnormal MRI findings in most children with clinical diagnosis of primarily generalized seizure, MRI was the study of choice in assisting the precise classification of epilepsy.

The locations of abnormality in MRI were concordant to the EEG location in almost disease categories with statistical significance, except for the infectious category because of diffuse cerebral involvement in this group. However, this confirmed that MRI was superior to the EEG regarding specific diagnosis and localization.

Among the concordant, the authors found that there was poor to moderate agreement of the EEG and the MRI locations, similar to the study of Stears JC[8] that approximately 50% of cases showed inconsistencies in the EEG recordings and the MRI studies. This could be due to interictal or noninvasive EEG studies being performed. Moreover, seizures frequently begin in the areas of the brain that are relatively silent to scalp and sphenoid electrodes. Limitation to perform invasive EEG in children is noted.

For the organic brain abnormalities, such as cortical dysplasia, and mesial temporal sclerosis, the MRI location showed strong statistically significant association with EEG. For the brain tumors, even though there was no statistic proven because of too small a sample size, all of them had the same locations in both MRI and EEG. MRI is the imaging modality of choice to evaluate patients with epilepsy[11,13,14].

Conclusion

In the present study, the most common finding in children with epilepsy was cortical dysplasia followed by mesial temporal sclerosis. The MRI was the imaging of choice for evaluation of the structural abnormality and assisting in making the precise classification of epilepsy with good concordance with the clinical data and EEG findings.

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การตรวจคลื่นแม่เหล็กไฟฟ้าสมองของผู้ป่วยเด็กชัก ในโรงพยาบาลรามาธิบดี ตั้งแต่ พ.ศ. 2541 ถึง 2545

สรรทิพย์ วงศ์ลดารมย์, จิรพร เหล่าธรรมทัศน์, อนันต์นิตย์ วิสุทธิพันธ์, ฝากจิต สวาทสุต

ได้รวบรวมข้อมูลผู้ป่วยเด็กที่มาด้วยอาการชักและได้รับการตรวจคลื่นแม่เหล็กของสมอง (MRI) ในโรงพยาบาลรามาธิบดี ระหว่างปีพุทธศักราช 2541 ถึง 2545 และวิเคราะห์หาความสัมพันธ์ระหว่างความผิดปกติทางโครงสร้างสมองที่ตรวจพบจาก MRI กับ อาการทางคลินิกและ การตรวจคลื่นไฟฟ้าสมอง

ผลการศึกษาพบว่ามีผู้ป่วยเด็กชักที่อายุน้อยกว่า 15 ปี ได้รับการทำ MRI ทั้งสิ้น 100 ราย เป็นเด็กหญิง 57 ราย และเด็กชาย 43 ราย อายุระหว่าง 1 เดือน ถึง 14 ปี เฉลี่ย 7ปี 5 เดือน ในจำนวนนี้มีเด็ก 16 ราย มาด้วยอาการ primary generalized seizure และ 79 ราย มีอาการของ partial or complex partial seizure with or without secondary generalization. อีก 5 ราย มาด้วยกลุ่มอาการพิเศษ โดยสาเหตุของการชักที่พบบ่อยที่สุดในเด็กทั้งหมด คือ กลุ่มของความผิดปกติแต่กำเนิด โดยเฉพาะอย่างยิ่ง cortical dysplasia. และพบว่า cortical dysplasia เป็นสาเหตุการชักที่พบบ่อยที่สุด(31%) ในเด็กที่มีอาการของ partial with or without generalization รองมาคือ Mesial temporal sclerosis (24%) และ combined cortical dysplasia with mesial temporal sclerosis (13.9%) ในทุกกลุ่มโรคพบว่ามีความสอดคล้องกันอย่างมีนัยสำคัญทางสถิติระหว่างการตรวจคลื่นไฟฟ้าสมอง และการตรวจคลื่นแม่เหล็กไฟฟ้าของสมอง