Clinical, brain imaging, and electroencephalogram evaluation of cases of cerebral palsy with epilepsy

Hassan A. Hassan[a], Abdel N.Biomi Mohamed[b], Mohammad A.Hady Mohammad, Mohamed A. Gebreel[a], Waleed A. Hamed[a]

Background Cerebral palsy (CP) is a chronic disorder of movement and posture. It is the result of a nonprogressive damage of immature nervous system caused by several factors that have occurred in prenatal, perinatal, or postnatal periods. Epilepsy is one of the most common problems among patients with CP.

Objectives The aim of the study was to evaluate patients with epileptic CP by clinical findings, electroencephalogram (EEG), as well as cranial MRI findings.

Patients and methods This cross-sectional study was conducted on 70 patients, seen at pediatric neurology clinics at Al-Azhar University Hospitals. All patients were subjected to detailed medical history, detailed general and neurological examination, EEG, and MRI brain.

Result Spastic quadriplegia was the most common type, seen in 29 (41.4%) cases. Generalized tonic–clonic seizure was the most common type of convulsion in our cases (42.9%). EEG abnormalities were commonly seen in CP with epilepsy (78.6%). The most common MRI scan abnormalities in epileptic children with CP were brain atrophy.

Conclusion Spastic quadriplegia is the most common type of CP associated with seizures. EEG is a useful tool in detecting types of electrical discharges. MRI is the most useful tool in detecting the etiology of CP.

Sci J Al-Azhar Med Fac, Girls 2019 3:550–559

The Scientific Journal of Al-Azhar Medical Faculty, Girls
2019 3:550–559

Keywords: cerebral palsy, electroencephalogram, epilepsy, MRI

Departments of, [a]Pediatrics, [b]Radiology, [c]Neurology, Faculty of Medicine, Al Azhar University, Cairo, Egypt

Correspondence to Mohamed Amin Mohamed Gebreel, MD Pediatrics, 7105 street 9 Almokatam, Cairo, 11571, Egypt. Tel: 00201030438405; e-mail: mohamedgebreel37@gmail.com

Received: 10 December 2018 **Accepted:** 23 June 2019

Introduction

Cerebral palsy (CP) is a disorder of movement and posture, caused by a nonprogressive brain disease that usually occurs perinatally [1]. The most frequent complaint is delayed motor development at the appropriate age [2]. Its incidence has not declined in recent years despite advances in both obstetric and neonatal care [3]. It is a common problem with an incidence of 2 to 2.5/1000 live births. The most common pathological findings of CP are white matter injury owing to cerebral ischemia or hemorrhage especially in preterm infants [4].

It is the most common cause of motor disability as well as cognitive impairment in children [5]. Its types are well known and established. A study showed that 33% of the patients were hemiplegic, whereas 44% were diplegic, and 6% were quadriplegic [6]. Others have stated that hemiplegia is the most common form of CP among term neonates, and second to diplegia among children born premature [7,8]. It results from inflammation with excessive cytokine formation and oxidative stress with excess release of glutamate stimulating the excitotoxic cascade [9]. This cascade was induced by hypoxic ischemic and infectious mechanisms [10,11].

Epilepsy is one of the most common problems among patients with CP. It is defined as two or more unprovoked seizures [12]. It has been used as a marker of severity and prognosis of such patients [13,14]. It occurs owing to diffuse cortical malformations and perinatal arterial ischemic stroke [2,15,16].

Incidence of epilepsy varies widely depending on the underlying etiology and pathology in CP [2,17]. In patients with CP, they have symptomatic epilepsy which may continue into later life [18]. It occurs in 15–60% of patients with undefined course [13,19,20]. Children with CP may experience extensive brain injury including the cortex, white matter, and central nuclei, and therefore, they are liable to develop epilepsy [21]. In certain types of CP, there are higher rates of epilepsy, as approximately one-third of the patients with CP exhibit seizures, and this figure is proportional to the degree of motor and cognitive disabilities [21–23]. Although the white matter damage is the most common abnormality, but combined gray and white matter abnormalities are more common among children with hemiplegia [24,25]. In contrast, isolated gray matter damage is the least common finding in CP.

In preterm babies, periventricular white matter lesions occurred more often than in term children (90 vs. 20%, respectively) [26].

The aim of the study was to evaluate patients with epileptic CP by clinical findings, electroencephalogram (EEG), as well as cranial MRI findings.

Patients and methods

Study design

This cross-sectional study was conducted on 89 patients with CP associated with epileptic seizures. Only 70 of them fulfilled our inclusion criteria, comprising 40 (57.1%) males and 30 (42.9%) females, and their ages ranged from 4 months to 10 years seen at pediatric neurology clinics at Al-Azhar University Hospitals from January 2011to July 2012. This study was approved by the Hospital Research Ethics Committee and has been performed in accordance with the ethical standards as in Declaration of Helsinki (1964) and its later amendments, and a written informed consent was obtained from patient's family. A questionnaire was designed, and data were collected. The following data were recorded: age, sex, age of onset of seizures, type of CP, and type of epilepsy. A questionnaire was filled out also with maternal medical and obstetrics history. Available birth records of the children with CP were reviewed.

All participants were subjected to the following:

Thorough medical history, including personal (age, sex, order of sibling, and consanguinity); perinatal history, with stress on specific complications of pregnancy, premature rupture of membranes, prolonged labor, meconium staining of liquor, and preterm labor (before 37 weeks of pregnancy); postpartum variables, including low-birth-weight babies (below 2.5 kg at birth), birth asphyxia, prolonged jaundice, or NICU admission; and family, past, and developmental histories.

Detailed general and neurological examination with stress on motor system examination as well as cognitive and intellectual assessment was done.

EEG and MRI brain were done for all cases.

Inclusion criteria

All children with CP with epilepsy of more than 1 month and age less than 10 years were included. CP was defined as motor disabilities caused by nonprogressive damage to the developing brain [27]. It is divided into the spastic, dyskinetic, ataxic, and mixed subtypes [21]. The spastic subtype is further divided into unilateral (one side of the body is involved) and bilateral (both sides of the body are involved) types. The spastic bilateral type was further subdivided into quadriplegia and diplegia [28]. Epilepsy was diagnosed according to Commission of Classification and Terminology. Active epilepsy was considered when two or more unprovoked seizures occurred [21,29–31].

Interictal EEG and cranial (MRI) findings were evaluated.

(1) Interictal models of EEG were performed using different modes of EEG machines. The electrodes were placed according to 10–20 international system of electrode placement. Bipolar as well as referential montages were applied. Sleep records were also obtained using chloral hydrate (50 mg/kg body weight orally). Awake EEG was also obtained for older children using hyperventilation and photic stimulation as provocative methods.
(2) Brain MRI was performed using: 1.5 T superconductive magnet (GE, Kurnbach, Germany).

Examination was performed using standard head coil: the patient was placed supine and positioned comfortably using a knee cushion with the head on the head rest. Head fixation band was used to prevent any movements. MRI scan included axial 10 mm weighted spin echo 500/10-16/1-2 (TR/TELNEX), axial 10 mm T2-weighted spin echo 3000–4000/98-105/1-2 (TR/TE/excitations, ms), and coronal fast spin echo 5 mm, 4000/105 (TR/TE/NEX).

Statistical analysis

The data were collected and entered into the personal computer. Statistical analysis was done using Statistical Package for the Social Sciences (SPSS, version 20) software. Arithmetic mean and SD were used for categorized variables. χ^2 test was used categorical variables, whereas for numerical data, t test was used to compare groups. The correlation was analyzed by Spearman correlation coefficients. The level of significance was 0.05.

Results

In our study, 57.1% were males, whereas 42.9% were females (Table 1). Their ages ranged from 4 months to 10 years (Table 2).

Our study showed that spastic quadriplegia was the most common type of CP, representing 41.4%, followed by spastic hemiplegia (20%), spastic diplegia (17.1%), mixed (14.3%), and athetoid (7.1%) (Table 3).

Our study showed that 47.1% of the patients with CP developed their first attack of seizures within a year of birth, 34.4% from 1 to 6 years, and only 18.3% after their sixth birthday (Table 4). Generalized tonic–clonic convulsions were the most common type (42.9%) followed by partial seizures (20%), infantile spasm (14.3%), myoclonic seizures (11.4%), and partial onset with secondary generalization (11.4%) (Table 5). These seizures are controlled in 48 (68.6%) cases, whereas 22 (31.4%) cases were uncontrolled, as shown in Table 6.

We did EEG for all cases. The abnormalities were generalized activity in 48.6%, focal activity in 18.6%, and focal onset with secondary generalization in 11.4%, whereas it was normal in 15 cases (21.4%) (Table 7).

Table 1 Sex distribution in the studied cases

Sex	Number of patients [*n* (%)]
Male	40 (57.1)
Female	30 (42.9)
Total	70 (100)

Table 2 Age distribution in the studied cases

Age	*n* (%)
4 months to 2 years	33 (47.1)
3–4 years	19 (27.1)
5–6 years	2 (2.9)
7–8 years	9 (12.9)
9–10 years	7 (10)
Total	70 (100)

Table 3 Clinical types of cerebral palsy

Type of CP	*n* (%)
Spastic quadriplegia	29 (41.4)
Spastic hemiplegia	14 (20)
Spastic diplegia	12 (17.1)
Mixed	10 (14.3)
Athetoid	5 (7.1)
Total	70 (100)

CP, cerebral palsy.

We did MRI brain for all cases (70) and found that the most common finding was cerebral atrophy (44.3%) followed by periventricular leukomalacia (PVL) (10%), basal ganglia abnormalities (11.4%), old infarcts (8.5%), incomplete pachygyria (5.7%), delayed myelination (4.3%), intracranial hemorrhage (5.7%), brain malformation (2.9%), arachnoid cyst (2.9%), and brain calcification (2.9%). On the contrary, normal MRI finding in one case was diagnosed as spastic diplegia (1.4%) (Table 8).

Case 1 was a 7-year-old full-term male baby delivered by vaginal delivery. The patient presented with spasticity of four limbs. Generalized tonic–clonic seizures started at 1 year.

Case 2 was a 5-year-old preterm male patient delivered by cesarean section who presented with focal motor seizure on the left side (partial seizure) at 1.5 years, with delayed milestones and spasticity on the left side.

Case 3 was a 6-month-old preterm male baby delivered by cesarean section who presented with spasticity of four limbs, with generalized tonic–clonic seizures started at neonatal period.

Table 5 Types of epileptic seizures

Type of epilepsy	*n* (%)
Generalized tonic–clonic seizures	30 (42.9)
Partial seizures	14 (20)
Infantile spasm	10 (14.3)
Myoclonic seizures	8 (11.4)
Partial onset with secondary generalization	8 (11.4)
Total	70 (100)

Table 6 Seizures control in children with cerebral palsy in different types

	Controlled seizures (48)	Uncontrolled seizures (22)	χ^2	*P*
Spastic quadriplegia CP	18 (37.5)	11 (50)	0.97	0.32
Spastic diplegia CP	11 (22)	1 (4.5)	Fisher	0.08
Spastic hemiplegia CP	12 (25)	2 (9.1)	Fisher	0.19
Mixed CP	4 (8.4)	6 (27.3)	Fisher	0.06
Athetoid CP	3 (6.3)	2 (9.1)	Fisher	0.64

CP, cerebral palsy.

Table 4 Distribution of age at onset of seizures among epileptic cerebral palsy patients

Age of onset	Spastic quadriplegia	Spastic diplegia	Spastic hemiplegia	Mixed CP	Athetoid CP	Total	χ^2	*P*
>1 year	15	7	5	6	0	33 (47.1)	6.7	0.15
1–6 years	9	2	8	2	3	24 (34.4)	7.4	0.11
< 6 years	5	3	1	2	2	13 (18.3)	3.1	0.54

CP, cerebral palsy.

Table 7 Electroencephalogram finding in cerebral palsy patients with epilepsy

EEG finding	Generalized tonic–clonic seizure	Infantile spasm	Myoclonic seizure	Partial seizure	Partial seizure with secondary generalization	Total [*n* (%)]
Generalized activity	18	10	6	0	0	34 (48.6)
Focal activity	0	0	0	13	0	13 (18.6)
Focal onset with secondary generalization	0	0	0	0	8	8 (11.4)
Normal EEG	12	0	2	1	0	15(21.4)

EEG, electroencephalogram.

Table 8 MRI finding in the studied cases

MRI finding	Spastic quadriplegia CP (29)	Spastic diplegia CP (12)	Spastic hemiplegia CP (14)	Mixed CP (10)	Athetoid CP (5)	Total (70)
Diffuse brain atrophy	18	5	2	4	2	31 (44.3)
Basal ganglia abnormalities	2	0	0	3	3	8 (11.4)
Periventricular leukomalacia	3	3	1	0	0	7 (10)
Old ischemic infarct	1	0	5	0	0	6 (8.6)
Incomplete pachygyria	3	1	0	0	0	4 (5.7)
Intracerebral hemorrhage	0	0	3	0	0	3 (4.3)
Delayed myelination	1	0	0	2	0	3 (4.3)
Brain malformation	0	2	0	0	0	2 (2.9)
Arachnoid cyst	0	0	1	1	0	2 (2.9)
Brain calcification	1	0	1	0	0	2 (2.9)
Brain tumors	0	0	1	0	0	1 (1.4)
Normal MRI	0	1	0	0	0	1 (1.4)

CP, cerebral palsy.

Case 4 was a 1.5-year-old full-term male baby, delivered by normal vaginal delivery, presented by generalized myoclonic seizures at 4 month, with delayed milestone, spasticity of four limbs, and abnormal movements (mixed CP) (Figs 1–8).

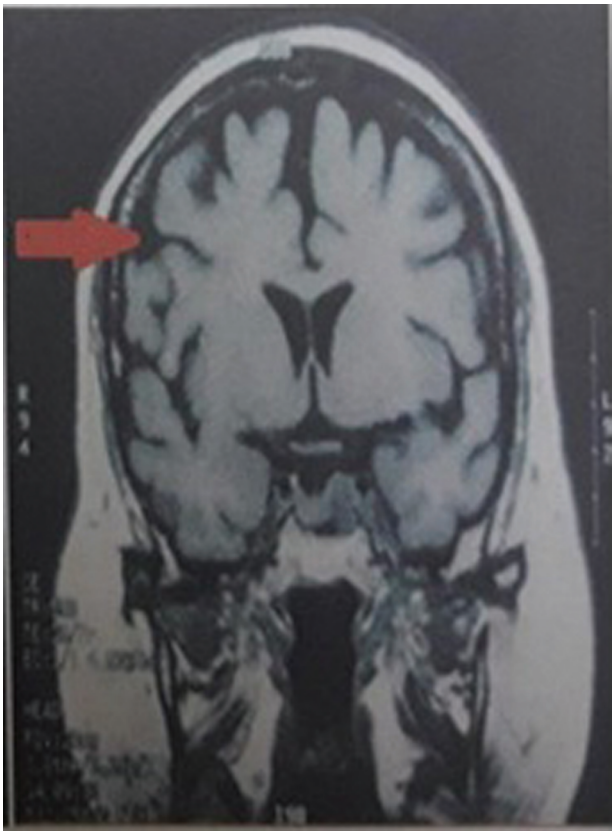
Discussion

We evaluated 70 patients with CP with epilepsy and found that 47.1% of them developed epilepsy within a year of birth, 34.3% of them had seizures onset from 1 to 6 years of age, and l8.6% had seizures onset after the age of 6 years. This is in agreement with Aksu [32] who found that 38.5% of patients with CP developed their first attack seizure by 1 year, whereas Kwong *et al.* [19] reported a higher incidence, where ~74% of children with epileptic CP had seizure onset in the first year of life, 34% had seizures from 1 to 6 years old, and 19% had seizures at older than 6 years. Other study done by Senbil *et al.* [33] found the age of onset of epilepsy of less than 12 months of age was seen in 51% of epileptic CP cases. On the contrary, Gururaj *et al.* [20] found that epilepsy in children with CP was presented in 78.6% of cases in the first year of life [34,35]. Bax *et al.* [27] found that 74% of the children with CP had their first seizure less than 12 months.

In our study, we found that generalized tonic–clonic seizure was the most common type of epilepsy (42.9%) (30 patients) followed by partial seizure in 14 (20%) patients, infantile spasm in 10 (14.3%) patients, partial onset with secondary generalization in eight (11.4%) patients, and myoclonic seizures in eight (11.4%). These generalized tonic–clonic seizures were common in spastic quadriplegic and spastic diplegic, whereas partial seizure was more common in spastic hemiplegic CP. This is in agreement with Senbil *et al.* [33] who found that generalized tonic–clonic seizures represented 45% of seizures in patients with CP. In other studies, generalized tonic–clonic seizures represented 38.1% of convulsions in patients with CP with high incidence in spastic diplegia, followed by infantile spasms (22%), then myoclonic seizures (l4.3%) and partial seizures (12.4%) [36]. Zafeirious *et al.* [27] found generalized tonic–clonic seizures in 44.4% of epileptic CP cases, simple partial seizures 32%, myoclonic seizures 25.2%, secondary generalized tonic–clonic 12.9%, and partial complex seizures

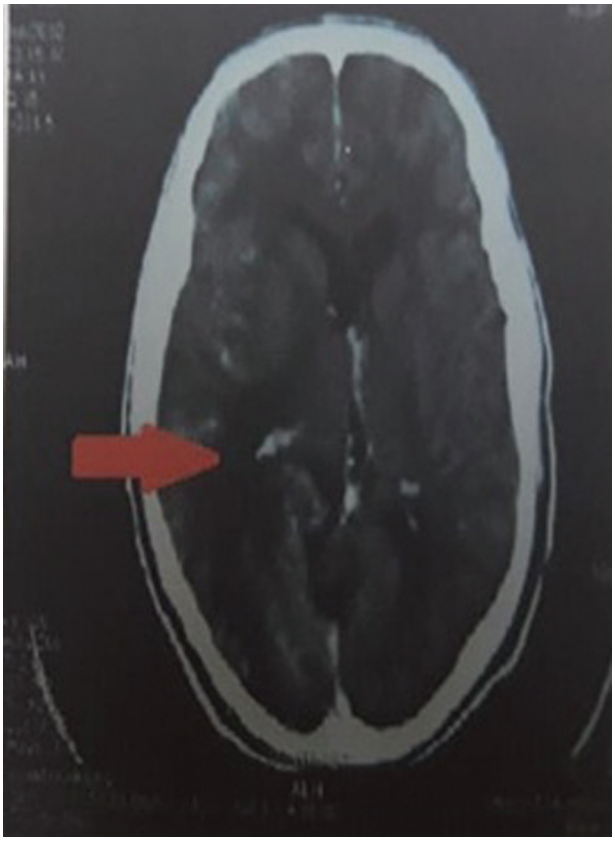
11.2%. Another study by Hamdy *et al.* [37] reported that 39.3% of children with CP had partial seizure, 32.1% had generalized tonic–clonic seizures, 14.3% had myoclonic seizure, 5.4% had infantile spasms, 5.4% had atonic, and 4.5% had unclassified/mixed seizure type.

Figure 1



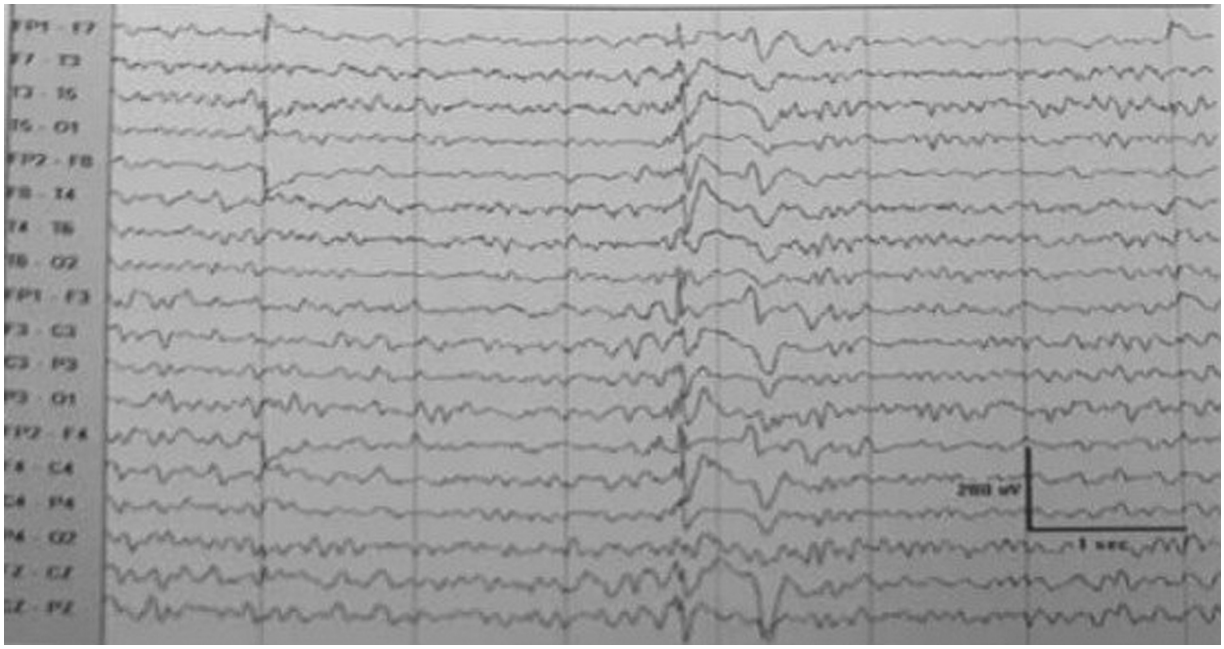
MRI shows cortical brain atrophy.

Figure 3



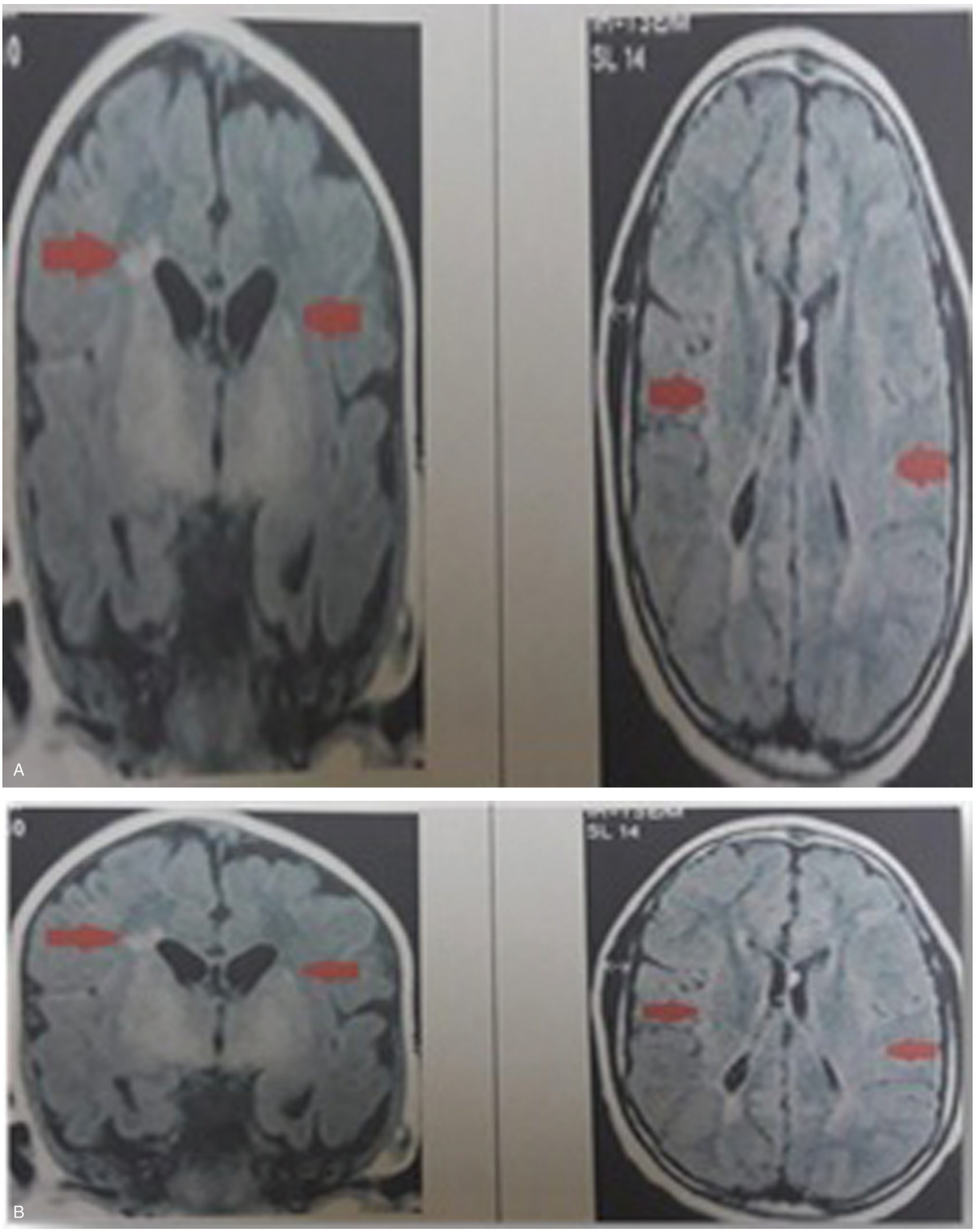
Axial MRI brain shows ischemic infarction at right occipital region.

Figure 2



EEG shows generalized spike, high amplitude, and after going background suppression and slow wave. EEG, electroencephalogram.

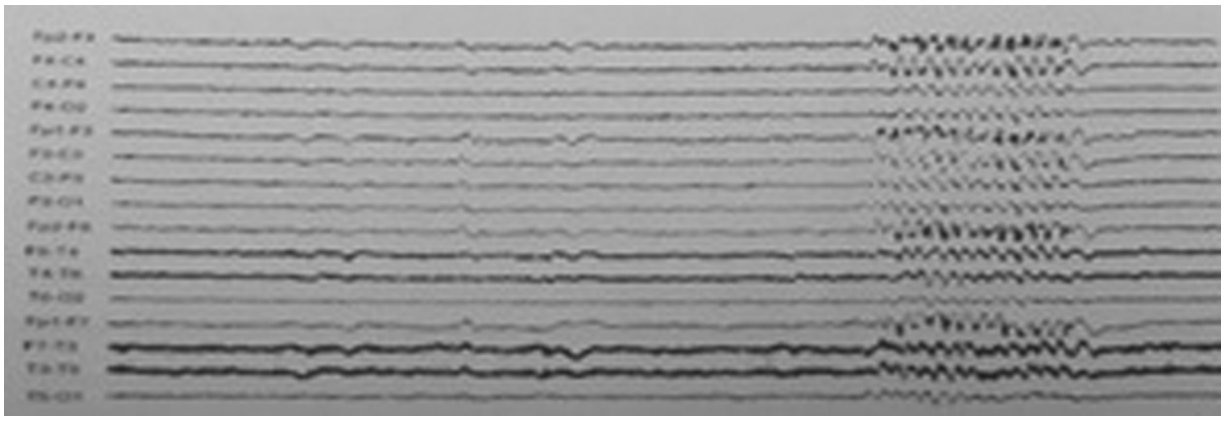
Figure 4



(a) Periventricular leukomalacia and (b) periventricular leukomalacia.

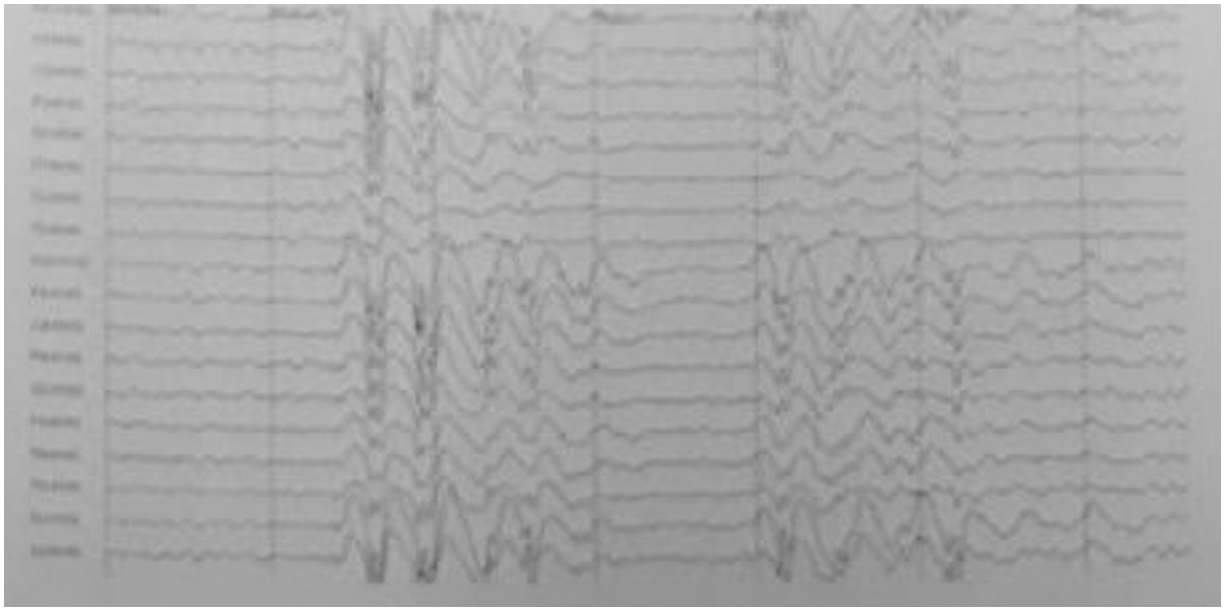
Niedermayer [38] clarified that the generalized epileptic activity can be attributed either to a genetic predisposition, or to a quick secondary bilateral synchronization. On rare occasions, deep subcortical cerebral lesion can also generate this kind of epileptic activity. The present study demonstrated that epilepsy in children with CP is controlled in 68.6% of cases but uncontrolled in 31.4% of cases according to its type. We studied seizures contol in different types of patients and found that 11/12 were controlled in spastic diplegia, 12/14 in spastic hemiplegia, 18/29 in spastic quadriplegia, 4/10 in mixed and 3/5 in athetoid so overall controlled in 48/70.

Figure 5



EEG shows generalized discharges of 3–4 Hz spike/multiple spike and slow waves. EEG, electroencephalogram.

Figure 6

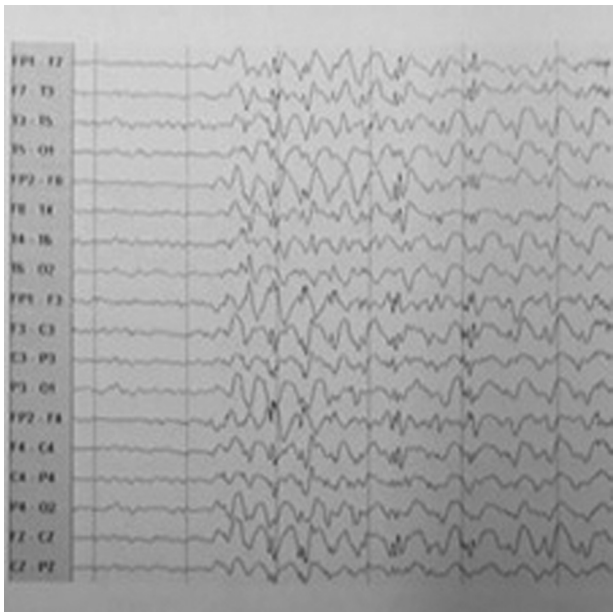


EEG shows epileptiform discharges (generalized spike and slow waves). EEG, electroencephalogram.

The abnormalities in EEG of our cases were 78.6%, representing 55 cases, whereas EEG was normal in 15 (21.4%). These abnormalities were generalized activity in 48.6%, focal activity in 18.6%, and focal onset with secondary generalization in 11.4%.

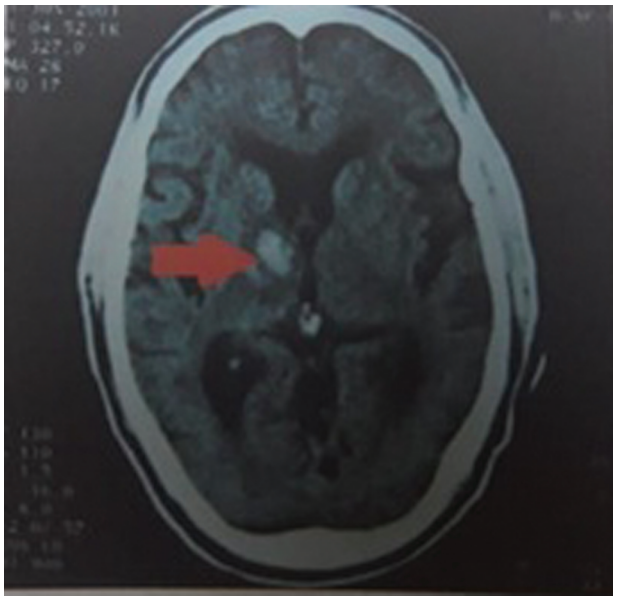
Normal EEG does not exclude epilepsy. Generalized activity is common in generalized tonic–clonic seizure, infantile spasm, and myoclonic seizure. Focal activity is common in partial seizure. Focal onset with secondary generalization is common in partial onset with secondary generalization. In our study, we noticed that abnormal EEG findings were predominant in spastic quadriplegic CP. However, normal EEG findings were predominant in spastic diplegic CP. Singhi *et al.* [36] stated that EEG abnormality seen in children with CP with epilepsy was 70.5%. These abnormalities included generalized activity, focal activity, and focal with secondary generalization, and 29.5% of cases had normal EEG findings. Aksu [32] and Delgado [39] reported that focal or secondary generalized activity EEG was common in children with CP. A study by Zafeirious *et al.* [27] stated that focal and generalized slowing was higher in the patients with epileptic CP (22.5 and 48.9%, respectively). Süssová *et al.* [40] reported a higher ratio of EEG focal disorder in patients with right hemiparetic CP. In contrast, Kwong *et al.* [19] demonstrated that generalized activity EEG was less frequently observed in patients with CP, whereas polymorphic seizure types were more common .They also observed more frequently partial seizures with

Figure 7



EEG shows slow spike wave complexes. EEG, electroencephalogram.

Figure 8



Basal ganglion hemorrhage.

secondary generalized in patients with epileptic CP. Data from studies involving 1918 children found that 43% (range, 35–62%) of children with CP developed epilepsy [2]. The prevalence of epilepsy varies depending on the type of CP that is present. Children with spastic quadriplegia have 50–94% epilepsy, whereas hemiplegics have about 30% incidence of epilepsy. The least prevalence was observed in patients with diplegia or ataxic CP at 16–27% [41]. In patients with dyskinetic CP, it may be difficult to differentiate partial complex seizures from dyskinetic movements [34]. American Academy of Neurology concluded that although ~45% of children with CP develop epilepsy, there is no evidence that EEG was useful in determining the etiology of CP as seen in retrospective studies involving 2014 patients with CP [2].In our study, cranial MRI findings were abnormal in 69 (98.6%) out of 70 cases and normal in only 1 (1.4%) case. These abnormalities were cerebral atrophy (44.2%) (the most common finding) followed by PVL (11.4%), basal ganglia abnormalities (10%), old infarcts (8.5%), incomplete pachygyria (5.7%), intracranial hemorrhage (5.7%), delayed myelination (4.3%), brain malformation (2.9%), arachnoid cyst (2.9%), brain tumor (2.9), and brain calcification (2.9%). Data from studies on 620 patients found that MRI scans were abnormal in 332/335 (99%) in preterm infants, 251/272 (92%) in term infants, and 23/29 (79%) infants older than 1 month [34,42]. MRI is the most sensitive tool in detecting PVL, other prenatally acquired lesions, as well as subtle congenital anomalies of brain development [43,44]. Other studies were done on 286 patients showed the percent of patients with an abnormal MRI scan based on the type of CP and revealed that 100% abnormalities was noticed in mixed type of CP, 98% in quadriplegic type, 96% in hemiplegic, 94% in diplegic, 75% in ataxic, 70% in dyskinetic, and 67% in atonic type [40,45–47]. Others reported that the most common MRI patterns in children with CP were periventricular white matter lesions (83%) that occur mainly in preterm infants and only 20% of term infants [10]. In many studies, higher incidence of periventricular changes in preterm infants and gray matter abnormalities in term infants is reported [26,48]. PVL is not uncommon among full-term infants as well as preterms. The study by Kwong *et al.* [19] of 122 patients with spastic CP reported one-third of term infants exhibited signs of white matter damage.

Study limitations

Our study was limited by small sample size. Some cases did not fulfill our inclusion criteria either owing to difficulties in achieving MRI or lack of health records. However, this study raises interesting issues requiring further studies involving more investigations such as metabolic screen and genetic study for better assessment and etiological identification of CP.

Conclusion

Our study confirmed that spastic quadriplegia was the commonest type of CP associated with seizures.

Generalized tonic–clonic seizures were the commonest type of seizures followed by partial seizures. Generalized activity in EEG finding was the commonest one. Brain atrophy, PVL, old infarcts, and basal ganglia abnormalities were common MRI scan findings in patients with epileptic CP. MRI is a more sensitive tool in the assessment of brain damage, resulting in perinatal asphyxia and congenital brain malformations. EEG and brain imaging taken together might lead clinicians toward a probable cause of CP.

Financial support and sponsorship
Nil.

Conflicts of interest
There are no conflicts of interest.

References

1 Nelson KB, Ellenberg JH. Epidemiology of cerebral palsy. *Adv Neurol* 1978; **19**:421–435.

2 Ashwal S, Russman BS, Blasco PA, Miller G, Sandler A, Shevell M, Stevenson R; Quality Standards Subcommittee of the American Academy of Neurology; Practice Committee of the Child Neurology Society. Practice parameter: diagnostic assessment of the child with cerebral palsy: report of the Quality Standards Subcommittee of the American Academy of Neurology and the Practice Committee of the Child Neurology Society. *Neurology* 2004; **62**:851–863.

3 Fereshteh N., Masomeh P, Khosheh K, Nahid M. Cerebral palsy and patterns of magnetic resonance imaging (MRI). *Iran Rehabil J* 2014; **12**:22.

4 Reid SM, Dagia CD, Ditchfield MR, Carlin JB, Meehan EM, Reddihough DS. An Australian population study of factors associated with MRI patterns in cerebral palsy. *Dev Med Child Neurol* 2014; **56**:178–184.

5 Odding E, Roebroeck ME, Stam HJ. The epidemiology of cerebral palsy: incidence, impairments and risk factors. *Disabil Rehabil* 2006; **28**:183–191.

6 Hagberg B, Hagberg G, Beckung E, Uvebrant P. Changing panorama of cerebral palsy in Sweden. VIII. Prevalence and origin in the birth year period 1991–94. *Acta Paediatr* 2001; **90**:271–277.

7 Soleimani F, Vameghi R, Rassafiani M, Fahimi NA, Nobakht Z. Cerebral palsy: motor types, gross motor function and associated disorders. *Iran Rehabil J* 2011; **9**:21–31.

8 Soleimani F, Zaheri F, Abdi F. Long-term neurodevelopmental outcomes after preterm birth. *Iran Red Crescent Med J* 2014; **16**:e17965.

9 Soleimani F, Teymouri R, Biglarian A. Predicting developmental disorder in infants using an artificial neural network. *Acta Med Iran* 2013; **51**:347–52.

10 Yoon BH, Romero R, Park JS, Kim CJ, Kim SH, Choi JH, *et al.* Fetal exposure to an intra amniotic inflammation and the development of cerebral palsy at the age of three years. *Am J Obstet Gynecol* 2000; **182**:675–781.

11 Minagawa K, Tsuji Y, Ueda H, Koyama K, Tanizawa K, Okamura H, *et al.* Possible correlation between high levels of IL-18 in the cord blood of pre-term infants and neonatal development of periventricular leukomalacia and cerebral palsy. *Cytokine* 2002; **17**:164–70.

12 Guidelines for Epidemiologic Studies on Epilepsy. Commission on epidemiology and prognosis, international league against epilepsy. *Epilepsia* 1993; **34**:592–596.

13 Sellier E, Uldall P, Calado E, Sigurdardottir S, eiMaria Torrioli G, Plattg MG, ChristineCans C. Epilepsy and cerebral palsy: characteristics and trends in children born in 1976–1998. *Eur J Paediatr Neurol* 2012; **16**:48–55.

14 Okumura A, Hayakawa F, Kato T, Kuno K, Watanabe K. Epilepsy in patients with spastic cerebral palsy: correlation with MRI findings at 5 years of age. *Brain Dev* 1999; **21**:540–543.

15 Reid SM, Dagia CD, Ditchfield MR, Reddihough DS. Grey matter injury patterns in cerebral palsy: associations between structural involvement on MRI and clinical outcomes. *Dev Med Child Neurol* 2015; **57**:1159–1167.

16 Carlsson M, Hagberg G, Olsson I. Clinical and aetiological aspects of epilepsy in children with cerebral palsy. *Dev Med Child Neurol* 2003; **45**:371–37.

17 Fukuda K, Kirino T, Fujiwara Y, Nagai S, Endo S. Clinical aspects of epilepsy in children with periventricular leukomalacia [in Japanese]. *No To Hattatsu* 2010; **42**:291–295.

18 Zelnik N, Konopnicki M, Bennett-Back O, Castel-Deutsch T, Tirosh E. Risk factors for epilepsy in children with cerebral palsy. *Eur J Paediatr Neurol* 2010; **14**:67–72.

19 Kwong KL, Wong SN, So KT. Epilepsy in children with cerebral palsy. *Pediatr Neurol* 1998; **19**:31–36.

20 Gururaj AK, Sztriha L, Bener A, Dawodu A, Eapen V. Epilepsy in children with cerebral palsy. *Seizure* 2003; **12**:110–114.

21 Andersen GL, Irgens LM, Haagaas I, Skranes JS, Meberg AE, Vik T. Cerebral palsy in Norway: prevalence, subtypes and severity. *Eur J Paediatr Neurol* 2008; **12**:4–13.

22 Suma P, SánchesLópez A, Pedrola GD, Ponces VJ, Boira CM. Considerations about childhood cerebral palsy and their relationship electroencephalographic disorders and epilepsy. *An Esp Pediatr* 1988; **28**:197–200.

23 Benassi G, Guarino M, Cammarata S, Cristoni P, Fantini MP, Ancona A, *et al.* An epidemiological study on severe mental retardation among school children in Bologna, Italy. *Dev Med Child Neurol* 1990; **32**:895–901.

24 Arts WFH, Visser LH, Loonen MCB, Tjiam AT, Stroink H, Stuurmanm PM. Follow up of 146 children with epilepsy after withdrawal of antiepileptic therapy. *Epilepsia* 1988; **29**:244–250.

25 Glenn O, Barkovich A. Magnetic resonance imaging of the fetal brain and spine: an increasingly important tool in prenatal diagnosis, Part 1. *Am J Neuroradiol* 2006; **27**:1604–1611.

26 Krageloh-Mann I, Horber V. The role of magnetic resonance imaging in elucidating the pathogenesis of cerebral palsy: a systematic review. *Dev Med Child Neurol J* 2007; **49**:144–145.

27 Bax MC. Terminology and classification of cerebral palsy. *Dev Med Child Neurol* 1964; **6**:295–297.

28 El-Tallawy HN, Farghaly WM, Shehata GA, Metwally NA, Rageh TA, Abo-Elfetoh N. Epidemiology of cerebral palsy in El-Kharga District-New Valley (Egypt). *Brain Dev* 2011; **33**:406–411.

29 Curatolo P, Arpino C, Stazi MA, Medda E. Risk factors for the cooccurrence of partial epilepsy, cerebral palsy and mental retardation. *Dev Med Child Neurol* 1995; **37**:776–782.

30 Ellenberg JH, Nelson KB. Early recognition of infants at high risk for cerebral palsy: examination at age four months. *Dev Med Child Neurol* 1981; **23**:705–716.

31 Ingram T. *Paediatric aspects of cerebral palsy*. Edinburgh: Churchill Livingstone; 1964.

32 Aksu E. Nature and prognosis of seizures in patients with cerebral palsy. *Dev Med Child Neurol* 1990; **32**:661–668.

33 Senbil N, Sonel B, Aydin O, Gurer Y. Epileptic and non epileptic cerebral palsy EEG, cranial imaging findings. *Brain Dev* 2002; **24**:166–169.

34 Bruck I, Antoniuk SA, Spessatto A, Bem RS, Hausberger R, Pacheco CG. Epilepsy in children with cerebral palsy. *Arq Neuropsiquiatr* 2001; **59**:35–39.

35 Rosenbaum P, Paneth N, Leviton A, Goldstein M, Bax M, Damiano D, *et al.* A report: the definition and classification of cerebral palsy April 2006. *Dev Med Child Neurol Suppl* 2007; **109**:8–14.

36 Singhi P, Jagirdar S, khandelwal N, Malhi P. Epilepsy in children with cerebral palsy. *J Child Neurol* 2003; **18**:174–179.

37 Hamdy NE, Wafaa MAF, Ghaydaa AS, Reda B, Tarek AR. Epileptic and cognitive changes in children with cerebral palsy: an Egyptian study. *Neuropsychiatr Dis Treat* 2014; **10**:971–975.

38 Niedermayer E. Abnormal EEG patterns (epileptic and paroxysmal). In: Niedermayer E, DaSilva FL, (eds). *Electroencephalography: basic principles, clinical applications and related fields*. Baltimore: Urban & Schwarzemberg; 1987 405–510.

39 Delgado M. Discontinuation of drug treatment after two seizure free years in children with cerebral palsy. *Pediatrics* 1996; **97**:192–197.

40 Süssová J, Seidl Z, Faber J. Hemiparetic forms of cerebral palsy in relation to epilepsy and mental retardation. *Dev Med Child Neurol* 1990; **32**:792–795.

41 Al-Sulaiman A. Electroencephalographic findings in children with cerebral palsy. *Funct Neurol* 2001;**16**:325–328.

42 Cioni G, Sales B, Paolicelli PB, Petacchi E, Scusa MF, Canapicchi R. MRI and clinical characteristics of children with hemiplegic cerebral palsy. *Neuropediatrics* 1999; **30**:249–255.

43 Jaw TS, Jong YJ, Sheu RS. Etiology, timing of insult, and neuropathology of cerebral palsy evaluated with magnetic resonance imaging. *J Formos Med Assoc* 1998; **97**:239–246.

44 Sugimoto T, Woo M, Nishida N. When do brain abnormalities in cerebral palsy occur? An MRI study. *Dev Med Child Neurol* 1995; **37**: 285–292.

45 Okumura A, Kato T, Kuno K, Hayakawa F, Watanabe K. MRI findings in patients with spastic cerebral palsy.*II: correlation with type of cerebral palsy*. *Dev Med Child Neurol* 1997; **39**:369–372.

46 Hayakawa K, Kanda T, Hashimoto K. MR imaging of spastic diplegia.*The importance of corpus callosum*. *Acta Radiol* 1996; **37**:830–836.

47 Yokochi K, Aiba K, Kodama M, Fujimoto S. Magnetic resonance imaging in athetotic cerebral palsied children. *Acta Paediatr Scand* 1991; **80**:818–823.

48 Mallard C, Wang X. Infection-induced vulnerability of perinatal brain injury. *Neurol Res Int* 2012; **10**:1–7.