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ORIGINAL ARTICLE

Attention deficit hyperactivity disorder (ADHD) in children with epilepsy

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Abstract

Background Attention deficit hyperactivity disorder (ADHD) is a common comorbidity of childhood epilepsy. ADHD symptoms in children with epilepsy have been studied since 1970s in western countries. However, relative studies are still rather limited in China.
Aims To study the incidence rate of ADHD in children with epilepsy, and further analyze the relationship of epilepsy and ADHD in China.
Materials and methods 206 children (age 6–16) with epilepsy and 58 healthy controls underwent assessment instruments (DSM-IV ADHD, ADHD Rating Scale-IV, and SNAP-IV Rating Scale).
Results The prevalence of comorbid ADHD was significantly higher in children with epilepsy (24.76%) than that in controls (5.17%), and inattentive subtype (ADHD-I, 14.1%) was the most prevalent. ADHD in childhood epilepsy was associated with younger age, early first onset age, and high frequency of epileptic seizures. There was no significant difference of ADHD incidence rate regarding the seizure type and abnormal electroencephalogram (EEG) discharges. The ADHD comorbidity rate in children treated with antiepileptic drugs (AEDs) (27.6%) was higher than that without AEDs therapy (14.0%); multiple AEDs were associated with a higher rate of ADHD comorbidity as compared with single AEDs. The incidence of comorbid ADHD in epileptic children treated with traditional single AEDs was significantly higher than those treated with novel single AEDs.
Conclusion Children with epilepsy have more attention problems as compared with healthy controls. ADHD in childhood epilepsy is associated with male sex, younger age, early first onset age, high frequency of epileptic seizures, and multiple AEDs.

Keywords Antiepileptic drugs · Attention deficit hyperactivity disorder · Children · Comorbid · Epilepsy

Introduction

Epilepsy is the most common neurological disorder characterized by sudden, temporary, and recurrent epileptic seizures, with an incidence rate of 0.5–1% in children and adolescents [1, 2]. Epilepsy is a major public health concern, which may cause disability, interfering with the ability to learn, and negative impact on social and psychological function [3–5]. The situation is even worse when attention deficit hyperactivity disorder (ADHD) occurs, a common comorbidity of childhood epilepsy [6–8].

ADHD is a common developmental disorder in childhood with three subtypes, including inattentive (ADHD-I), hyperactive/impulsive (ADHD-HI), and combined type (ADHD-C). The incidence of ADHD is 3–7% in general school–aged children [9]. However, the prevalence of ADHD ranges from 8 to 77% in children with epilepsy, based on different samples and diagnostic criteria [2, 10, 11]. As compared with epileptic children, the quality of life is dramatically decreased in children with epilepsy and comorbid ADHD [12]. Early recognition and diagnosis of coexisting ADHD, and timely intervention and treatment measures are necessary for the improvement of the prognosis in this group of children.

Studies on ADHD symptoms in children with epilepsy originated from 1970s in western countries [13]. Since then, numerous researches have been focused on the comorbid ADHD in epilepsy population [6, 14–18]. However, the relationship of epilepsy and ADHD is still not well elucidated. Great heterogeneity exists in the study design, subjects'

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enrollment, assessment tools, and diagnostic criteria in these studies. Moreover, relative studies are still rather limited in China [18–20]. In the present study, we studied the incidence rate of ADHD in 206 children with epilepsy, and further analyzed the relationship between ADHD and patient's characteristics (sex/age), seizure (first onset age, duration, frequency, seizure type, and EEG abnormalities, etc.), and treatment-related factors (antiepileptic drugs).

Methods

Participants

During the period from June 2013 to February 2014, 206 children aged 6–16 years with epilepsy were recruited. The initial selection criteria included the following: (i) aged from 6 to 16 years; (ii) diagnosis of epilepsy and classification of seizures according to the diagnostic and classification criteria designated by the International League Against Epilepsy (ILAE); (iii) no abnormal findings in the physical examination of the nervous system; (iv) willing to participate in the survey and can complete the questionnaire. Epilepsy children were excluded from the study if they met the following criteria: (i) children with significant mental retardation (Wechsler Intelligence Scale IQ < 70); (ii) children with chronic diseases such as asthma and diabetes. A total of 206 epilepsy children were finally included after a strict examination of the children's data, and elimination of invalid questionnaires.

Age- and gender-matched healthy children in the same area were selected as the control participants. Inclusion criteria were as follows: (i) no abnormal findings in the physical examination of the nervous system; (ii) no history of seizure or seizure-like episode; (iii) willing to participate in the survey and can complete the questionnaire. Children were excluded if they met the following criteria: (i) significant mental retardation (Wechsler Intelligence Scale IQ < 70); (ii) with chronic diseases such as asthma and diabetes. After elimination of invalid questionnaires, we finally included 58 healthy children as the control group. Informed consent was obtained from children and their guardians. The study was approved by the Ethic committee of Huazhong University of Science and Technology.

Assessment instruments

Assessment of DSM-IV ADHD

According to the DSM-IV (Diagnostic and Statistical Manual of Mental Disorders, 4th edition) from the American Psychiatric Association, the symptoms of ADHD are composed of two parts, including attention deficit and hyperactivity, with 9 items for each part. All of the following conditions are required for the diagnosis of children: (i) above symptoms present prior to age 7; (ii) symptoms occur in more than 2 occasions, such as schools, families, or others; (iii) defects in the learning, social, and other functions, with clinical evidence; (iv) excluding mental retardation and mental illness (including schizophrenia, mood disorder, anxiety, etc.). The specific ADHD subtypes predominantly include inattentive, hyperactive, and combined. The diagnosis of attention deficit or/and hyperactivity requires meeting more than 6 items each/both.

ADHD Rating Scale-IV

The ADHD Rating Scale-IV (ADHD-RS-IV), which is a rating scale for the symptoms of the children, is composed of 18 items, including 9 items for attention deficit and 9 for hyperactive. The frequency of symptoms is divided into four different grades: 0, rarely happens; 1, sometimes; 2, often happen; 3, very frequent. This assessment tool exerts an assistant role for in the diagnosis of ADHD, and provides a basis for the clinical identification of children with possible ADHD.

SNAP-IV Rating Scale

The Swanson, Nolan, and Pelham-IV (SNAP-IV) rating scale is composed of three parts, including attention deficit, hyperactivity, and oppositional defiant. This assessment tool also assisted in the identification of children with possible ADHD.

ADHD diagnosis

Clinical diagnosis of ADHD was carried out based on clinical manifestations, physical examination, observation and communication of patients, interviews with caregivers and teachers, screening instruments, psychological tests, intelligence tests, and mental specialist examinations. All diagnoses of ADHD were completed under the guidance of specialized neurologists and pediatricians.

Data analysis

Statistical analysis was carried out using SPSS 19.0. The rate of ADHD in children with epilepsy or healthy controls was described using percentages, and the comparison between two groups was done using chi-square test. The comparison of comorbid ADHD rate with different clinical symptoms of epilepsy was calculated using chi-square test or Fisher exact test. The risk factors of epilepsy children who had been treated with antiepileptic drugs and those who did not take antiepileptic drugs were analyzed by two classification logistic regression analysis. The probability value of < 0.05 was considered to be statistically significant.

Table 1 Demographic and clinical characteristics

	Epilepsy ($n = 206$)	Controls ($n = 58$)
Age (years, mean ± SD)	10.18 ± 2.50	11.24 ± 3.02
Sex		
Male (n, %)	136 (66.02)	30 (51.72)
Female (n, %)	70 (33.98)	28 (48.28)
Comorbid ADHD (n, %)	51 (24.76)	3 (5.17)
Subtypes of comorbid ADHD		
ADHD-I (n, %)	29 (14.08)	1 (1.72)
ADHD-HI (n, %)	7 (3.40)	0 (0.00)
ADHD-C (n, %)	15 (7.28)	2 (3.45)
Suspicious ADHD (n, %)	42 (20.39)	0 (0.00)

Results

Characterization of ADHD rate and type in children with epilepsy

The demographic and clinical characteristics of children with epilepsy and controls are shown in Table 1. Three (5.17%) out of the 58 controls were diagnosed with DSM-IV defined ADHD, while 51 (24.76%) out of the 206 children with epilepsy were diagnosed with DSM-IV defined ADHD (Table 1 and Fig. 1). The prevalence of ADHD was significantly higher in children with epilepsy than that in controls. According to the ADHD rating scale IV and SNAP-IV rating scale, 42 (20.39%) of the 206 children with epilepsy were identified as possibly having ADHD (Table 1). In total, the rate of ADHD and suspicious ADHD children was 45.1% (93) in children with epilepsy.

Among the 51 children with ADHD and epilepsy, 56.86% ($n = 29$) were inattentive subtype (ADHD-I), 13.73% ($n = 7$) were hyperactive (ADHD-HI) subtype, and 29.41% ($n = 15$) were combined (ADHD-C) subtype (Fig. 1).

Clinical factors associated with epilepsy

The first onset age of children with epilepsy was 7.37 ± 3.36 years, and the duration of epilepsy was 3.21 ± 2.47 years. The detailed information of epilepsy and clinical history of patients are shown in Table 2.

Demographics and comorbid ADHD

The prevalence of comorbid ADHD in epilepsy children regarding sex and age has been shown in Table 3. Male epilepsy children exhibited a significantly higher rate of ADHD (29.4%) as compared with their female counterparts (15.7%). The prevalence of ADHD in epileptic children aged 6–12 years (30.5%) was significantly higher than that in epileptic children aged 12–16 years (12.3%).

Epileptic seizures and comorbid ADHD

Among the 206 children with epilepsy, the first onset age of 9 children was below 1 year, and 6 (66.7%) of them had combined ADHD (Table 4). The incidence rate was gradually decreased in children with increasing first onset age, as 57.1% for 1–3 years of first onset, 27.9% for 3–6 years, and 15.8% for 6–16 years. Significant differences have been found among different age groups for first onset of epilepsy.

With regard to the duration of epilepsy, we classified patients into three categories, including less than 1 year, 1–3 years, and above 3 years. In the present study, we did not find statistical differences in the prevalence of ADHD in different durations of epilepsy (Table 4). However, the rate of ADHD was not significantly different regarding the frequency of epileptic seizures as shown in Table 4. We excluded 52 children with epilepsy for less than 1 year. The remaining children were divided into three categories, including no

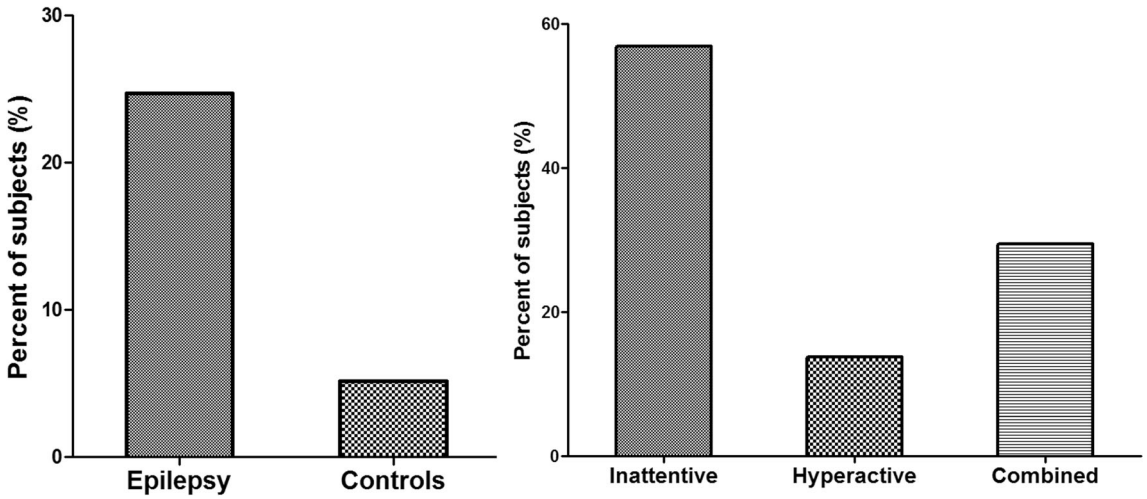

Fig. 1 Prevalence of ADHD in controls and children with epilepsy (left panel) and its subtype in epilepsy ADHD+ children (right panel)

Table 2 Clinical epilepsy features and clinical history of patients

Item	*n*	%
Seizure type		
Generalized: tonic–clonic	53	25.73
Generalized: absence	4	1.94
Simple partial	30	14.56
Complex partial	24	11.65
Partial seizures evolving to secondarily generalized	78	37.86
Unknown	17	8.25
Video-electroencephalogram (EEG)		
Not collected	18	8.74
Undetected epileptiform discharge	16	7.77
Symmetric epileptiform discharge	57	27.67
Focal epileptiform discharge	115	55.83
Classifications of focal epileptiform discharge		
Frontal area	23	11.17
Temporal area	16	7.77
The central area	19	9.22
Occipital region	14	6.80
Multiple parts	43	20.87
Antiepileptic drugs (AEDs)		
Not taking AEDs	43	20.87
Oxcarbazepine	32	15.53
Lamotrigine	13	6.31
Topiramate	15	7.28
Levetiracetam	16	7.77
Valproic acid	24	11.65
Carbamazepine	3	1.46
Phenobarbital	1	0.49
Epileptic Kang capsule (traditional Chinese medicine)	1	0.49
Multiple AEDs	58	28.16
Clinical history		
History of febrile convulsion	35	16.99
Family history of epilepsy	12	5.83
Perinatal abnormal history	29	14.08
Abnormality of the head	35	16.99

Table 3 Prevalence of ADHD regarding sex and age in children with epilepsy

	No. of patients	Comorbid ADHD (*n*, %)	$\chi 2$	*P*
Sex				
Male	136	40 (29.4)		
Female	76	11 (15.7)	4.655	0.031
Age (years)				
6–11	141	43 (30.5)		
12–16	65	8 (12.3)	7.901	0.005

seizures in 1 year, < 1 time/3 months, and > 1 time/3 months; the incidence rate of comorbid ADHD was 17.8%, 20.8%, and 41.1%, respectively. Our results indicate that high frequency of epileptic seizures (seizures more than once every 3 months) is associated with a relatively high prevalence of ADHD.

The prevalence of comorbid ADHD was 35.8% (19 in 53 cases) in children with generalized tonic–clonic seizures, 16.7% in (5 in 30 cases) in children with simple partial, and 20.5% (16 in 78 cases) in children with partial seizures evolving to secondarily generalized (Table 5). There was no significant difference among the prevalence rate of ADHD regarding the seizure type among children with epilepsy.

Abnormal electroencephalogram and comorbid ADHD

Electroencephalogram (EEG) was obtained from 191 of 209 children. The incidence rate of comorbid ADHD in children with frontal, temporal, and central focus was around 20%, while in children with multifocal epileptiform discharge was above 30% (Table 6). No significant difference was observed regarding the rate of ADHD in different EEG abnormal discharges.

Antiepileptic drugs and ADHD

The incidence rate of comorbid ADHD in children taking antiepileptic drugs (AEDs) was 27.6% (45 in 163 cases), while that in children not taking AEDs was 14.0% (6 in 43 cases) (Table 7). The differences were not statistically significant although the rate of ADHD was slightly higher in children taking AEDs. However, almost half (43.1%) of the children taking multiple AEDs were diagnosed with comorbid ADHD, while the rate of ADHD was only 19.2% in children treated with single AEDs. The incidence rate of ADHD was significantly increased in children taking multiple AEDs (Table 7). We further compared the prevalence of ADHD in children who used single AEDs in comparison with the use of traditional AEDs (carbamazepine, phenobarbital, and valproic acid) or novel AEDs (oxcarbazepine, lamotrigine, topiramate, and levetiracetam). Our data revealed that incidence rate of ADHD was significantly reduced in children treated with novel AEDs (14.5%) than in children treated with traditional AEDs (32.1%) as shown in Table 7.

In our study, the least used AEDs was carbamazepine (3 of 209 children), phenobarbital (1 of 209 children), and epileptic Kang capsule (traditional Chinese medicine, 1 of 209 children). The number of children was similar with other single AEDs, with oxcarbazepine (32 children) the most commonly used. Forty-three children did not take AEDs, and 58 children took multiple AEDs. Symptoms of ADHD presented in 25 of 58 (43.1%) children taking multiple AEDs, 6 of 43 (14.0%) children without AEDs medication, and 3 of 32 (9.4%) children receiving oxcarbazepine. Our data showed that single

Table 4 Prevalence of ADHD by first onset age, duration, and frequency of epileptic seizures

	No. of patients	Comorbid ADHD (*n*, %)	$\chi 2$	*P*
First onset age (years)				
≤ 1	9	6 (66.7)		
1–3	21	12 (57.1)		
3–6	43	12 (27.9)		
6–16	133	21 (15.8)	23.5	0.000
Duration (years)				
< 1	52	9 (17.3)		
1–3	62	13 (21.0)		
> 3	92	29 (31.5)	4.287	0.017
Frequency of epileptic seizures				
No seizures in 1 years	45	8 (17.8)		
< 1 time/3 months	53	11 (20.8)		
> 1 time/3 months	56	23 (41.1)	8.556	0.014

AEDs medication was not significantly associated with change of incidence rate of ADHD as compared with children not taking AEDs, while multiple AEDs medications were significantly related to a higher rate of comorbid ADHD compared to children not taking AEDs (Table 8).

Discussion

The detection rate of ADHD in epilepsy is far higher than that of ADHD in children from the general population. The high detection rate suggests some influencing factors in children with epilepsy may promote the occurrence of ADHD. However, the pathogenesis of ADHD in epilepsy is not very clear. At present, experts have proposed many possible explanations of pathogenesis of epilepsy co-occurring with ADHD, such as dysplasia of the brain, the influence of epileptic seizures, epileptic discharge EEG, and the effect of antiepileptic drugs. This study assessed the incidence rate of ADHD in 206 children with epilepsy, and further analyzed the relationship between ADHD and patient's characteristics (sex/age), seizure (first onset age, duration, frequency, seizure type, and EEG abnormalities), and treatment-related factors (AEDs).

The prevalence of comorbid ADHD has been reported to range from 8 to 77%, with different samples enrolled and diagnosis criteria [2, 10, 11]. An incidence rate of 42.2% (81 in 192 children) has been reported by Han and colleagues [19]. Hermann et al. reported that 31.5% of the children with epilepsy had coexisting ADHD, while the prevalence rate of ADHD in the normal control group was only 6.4%. In the present study, we found that 51 of the 209 epileptic children presented with comorbid ADHD (24.76%), and the incidence rate was significantly higher as compared with controls (5.17%).

ADHD with epilepsy has its unique characteristics compared with simple ADHD. In simple ADHD, ADHD-C is the most important subtype. However, in epilepsy-related ADHD, ADHD-I is the most common subtype. Dunn et al. reported that ADHD-I was the most frequently observed subtype in 175 children and adolescents with epilepsy, with an incidence rate of 24% [6]. Tsai and colleges reported an incidence rate of 11.5% of ADHD-I, 4.9% of ADHD-HI, and 8.2% of ADHD-C in 61 patients with epilepsy [21]. In this study, 29 of the 209 (14.1%) epilepsy children were ADHD-I, 7 (3.4%) were ADHD-HI, and 15 (7.3%) were ADHD-C. Our results are consistent with other studies, indicating that ADHD-I is the most common subtype of comorbid ADHD in epileptic populations [6, 12, 21–23].

Table 5 Prevalence of ADHD by seizure type

	No. of patients	Comorbid ADHD (*n*, %)	$\chi 2$	*P*
Seizure type				
Generalized: tonic–clonic	53	19 (35.8)		
Generalized: absence	4	0 (0.00)		
Simple partial	30	5 (16.7)		
Complex partial	24	7 (29.2)		
Partial seizures evolving to secondarily generalized	78	16 (20.5)		
Unknown	17	4 (23.5)	6.122	0.276

Table 6 Prevalence of ADHD and abnormal discharge of electroencephalogram

	No. of patients (*n*)	Comorbid ADHD (*n*, %)	$\chi 2$	*P*
Video-electroencephalogram (EEG)				
Undetected epileptiform discharge	16	3 (18.8)		
Symmetric epileptiform discharge	57	14 (24.6)		
Focal epileptiform discharge	115	29 (25.2)	0.318	0.853
Focus of activity				
Frontal	23	6 (26.1)		
Temporal	16	3 (18.8)		
Central	19	3 (15.8)		
Occipital	14	3 (21.4)		
Multifocal	43	14 (32.6)	2.65	0.618

Clinical epidemiological studies on ADHD indicate that the prevalence of ADHD in pre-school and school-age boys is 3–9 times higher than that in girls [24]. However, there is controversy regarding gender differences in ADHD in epileptic children. Some studies found that there was no significant gender difference [25, 26]. Stores et al. [27] studied the attention and behavior problems of 71 epileptic children with average age of 11–12 years and 35 control subjects. They revealed that male epilepsy children have obvious ADHD-related problems compared with their female counterparts. Consistent with the findings of Stores et al., here we found that male epilepsy children exhibited a significantly higher rate of ADHD (29.4%) as compared with their female counterparts (15.7%). This controversy may originate from the differences in the populations included in the study, and may also be related to the sample size. Further studies with large sample size should be carried out to test whether the epileptic boys are more behaviorally vulnerable.

A negative relationship between age and hyperactivity/impulsiveness has been reported, and fewer symptoms have been reported in older children [28]. In the present study, epilepsy children aged 6–12 years had a significantly higher prevalence of ADHD (30.5%) compared to epilepsy children aged 12–16 years (12.3%). Besides, in our sample, the incidence rate of comorbid ADHD in children with first onset age of epilepsy < 1 year was significantly higher than in children with first onset age of epilepsy > 1 year. Similarly, Bruce et al. [22] found that the incidence of ADHD comorbidity in children with new onset epilepsy is closely related to the age of first seizure. Our study further verifies that the early first onset of epilepsy and younger age are probably risk factors for the development of ADHD in children with epilepsy.

The relationship between seizures type and ADHD is also controversial. There are reports that there is no significant correlation between the type of epileptic seizures and ADHD [6, 26]. Other studies report that children with generalized tonic–clonic seizures are more likely to co-develop ADHD [29, 30]. In our subjects, we found that the incidence rate of coexisting ADHD was higher in children with generalized: tonic–clonic seizures, but the difference was not statistically significant.

To date, there have been many studies regarding the relationship between EEG and ADHD. It is found that ADHD children are more accompanied by EEG abnormality than ordinary children. However, there is no strong evidence about the abnormal EEG in children with epilepsy. At present, there are many studies about pure ADHD and EEG abnormal discharge. Richter et al. [31] reported that 6.1% epileptic discharges were found in 347 children with ADHD. Although abnormal discharge of EEG can be found in ADHD patients, the effect of EEG abnormality on ADHD is still not determined. Clarke and colleges [32] studied the effect of stimulant

Table 7 Prevalence of ADHD and antiepileptic drugs (AEDs) medication

	No. of patients (*n*)	Comorbid ADHD (*n*, %)	$\chi 2$	*P*
Antiepileptic drugs (AEDs) medication				
Taking AEDs	43	6 (14.0)		
Not taking AEDs	163	45 (27.6)	3.405	0.065
Types of AEDs medication				
Single AEDs	104	20 (19.2)		
Multiple AEDs	58	25 (43.1)	10.577	0.0001
Single AEDs medication				
Traditional AEDs	28	9 (32.1)		
Novel AEDs	76	11 (14.5)	4.113	0.043

Table 8 Prevalence of ADHD by different antiepileptic drugs

Antiepileptic drugs (AEDs) treatment	No. of patients (*n*)	Comorbid ADHD (*n*, %)	$\chi 2$	*P*
Not taking AEDs	43	6 (14.0)		
Oxcarbazepine	32	3 (9.4)	0.06	0.807
Lamotrigine	13	0 (0.0)	0.835	0.361
Topiramate	15	4 (26.7)	0.526	0.468
Levetiracetam	16	4 (25.0)	0.378	0.538
Valproic acid	24	8 (33.3)	3.5	0.061
Multiple AEDs	58	25 (43.1)	9.864	0.002

(methylphenidate and amphetamines) on abnormal EEG in 50 ADHD patients, and their results showed that the abnormal discharge can be improved. There is also evidence that EEG discharges may also cause damage to cognition and attention [33, 34]. However, there is no significant correlation between EEG and ADHD in this study. Previous studies have pointed out that frontal dysfunction may lead to higher incidence of ADHD [35, 36]. In this study, the incidence of ADHD in patients with focal epileptiform discharge is slightly higher, but there is no significant difference compared with other parts.

The incidence rate of ADHD in children with epilepsy is higher than that of the general population, and the effect of antiepileptic drugs needs to be considered. Traditional AEDs may cause damage to cognitive function and attention. It has been reported that phenobarbital might cause symptoms of ADHD and benzodiazepines may lead to attentional deficit [37]. Valproic acid is the latest launched traditional AEDs. Compared with phenobarbital, phenytoin, and other traditional medicine, valproic acid had a relatively small effect on cognitive function and behavior. Single drug effect of valproic acid on cognitive function impairment disappears after withdrawal of valproic acid [38–40]. The effects of new AEDs on cognitive function are relatively small compared to traditional AEDs. Lamotrigine is a new type of AEDs. It has been reported that lamotrigine combined with other antiepileptic drugs treatment did not cause cognitive decline and new adverse reactions in adult epilepsy [41]. Other studies [42, 43] revealed that lamotrigine was better than carbamazepine, topiramate, and valproic acid in cognitive and behavioral problems. However, the effect of lamotrigine on cognitive function in childhood has not been well studied.

In our samples, the ADHD comorbidity rate in children treated with AEDs (27.6%) was higher than that in children without AEDs therapy (14.0%), but the difference was not statistically significant. Moreover, the incidence of ADHD was significantly higher in children treated with multiple AEDs than those treated with single AEDs, suggesting the effects of a variety of drugs may make children with epilepsy more likely to show ADHD symptoms. In order to study the effect of single AEDs on comorbid ADHD in children with epilepsy, each single AEDs group was compared with children not taking AEDs, and no significant difference was found, suggesting oxcarbazepine, levetiracetam, topiramate, lamotrigine, and valproic acid had no obvious effect on ADHD comorbidity in children with epilepsy. However, the incidence of comorbid ADHD in epileptic children treated with traditional single AEDs was significantly higher than those treated with novel single AEDs, suggesting that traditional AEDs are more likely to be associated with ADHD.

In conclusion, our study revealed that children with epilepsy have more attention problems as compared with their counterparts from the general population. Seizure type did not predict coexisting ADHD in epileptic children. Early first onset age and younger age are risk factors for comorbid ADHD. Less frequency of epileptic seizures, single AEDs, and better control of epilepsy are important factors to reduce ADHD symptoms. It is generally believed that epilepsy itself and the use of AEDs may be harmful to cognition. In addition, it has been reported that abnormal development of the brain in epileptic patients is the cause of epileptic seizures and ADHD [44, 45]. For clinicians, timely detection and diagnosis of comorbid ADHD in epileptic children, giving appropriate intervention and treatment, can significantly improve the prognosis and improve the quality of life of children with epilepsy.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent Informed consent was obtained from all individual participants included in the study.

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