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ORIGINAL ARTICLE

DWI scoring system for prognosis of acute encephalopathy with biphasic seizures and late reduced diffusion

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Abstract

Purpose The aim of this study was to predict neurological outcomes for acute encephalopathy with biphasic seizures and late reduced diffusion (AESD) using diffusion-weighted imaging (DWI), and assess relationships between anatomical sites of lesions and their outcomes.

Materials and methods We assessed DWI abnormalities and neurological outcomes in 30 patients with AESD, and classified patients into severe and non-severe groups according to their neurological outcomes. We also established a DWI scoring system as follows: zero for normal, and one for lesion at each location. Differences between the severe and non-severe groups were examined, and receiver operating characteristic (ROC) curve analysis was performed.

Results Nine (30%) patients were classified into the severe group. On DWI, patients in the severe group were more likely to have temporal lobe ($P=0.014$), perirolandic ($P=0.008$), and corpus callosum ($P=0.0008$) lesions than those in the non-severe group. The total DWI scores were significantly higher in the severe group than those in the non-severe group ($P=0.0002$). ROC curve showed an area under the curve of 0.929, with a cutoff value of five, sensitivity of 88.9%, and specificity of 81.0%.

Conclusion Patients with severe AESD had more extensive DWI abnormalities than those with non-severe AESD. Our DWI scoring system may be useful for the prediction of outcomes of AESD. Widespread lesions seemed to have stronger influence on outcomes than each lesion location.

Introduction

Acute encephalopathy with biphasic seizures and late reduced diffusion (AESD) is the most common subtype of infectious pediatric encephalopathy in Japan [1]. AESD is characterized by a febrile seizure on day 1, with secondary seizures on days 4–6. During the first 2 days, there are no abnormal findings on magnetic resonance (MR) imaging. However, over days 3–9, diffusion-weighted imaging (DWI) and apparent diffusion coefficient (ADC) maps show restricted diffusion in the subcortical white matter [2, 3]. AESD is also characterized by low mortality and a high incidence of neurological sequelae, which can vary from mild to severe [1–3]. An autopsy case of AESD showed evidence of loss of myelinated axons and gemistocytic astrocytes in the subcortical white matter, where restricted diffusion was observed on DWI [4]. Thus, restricted diffusion areas in the subcortical white matter in AESD patients may relate to irreversible brain damage, with more extensive lesions associated with worse neurological outcomes.

Predicting outcomes in severe AESD patients may allow targeting of treatments, such as cyclosporine, from the acute phase of injury [5]. There are few reports assessing prognostic factors for AESD [6–9]. Among these, only Lee et al. [7] assessed the prognostic factors of AESD using MR imaging, and showed that patients with severe AESD had significantly more extensive restricted diffusion areas than those with non-severe AESD. However, only quantitative analyses, without scoring of MR imaging, were used in that study, and only trends for prognostic factors were observed because of

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the small sample size. Thus, it is difficult to translate these findings into clinical practice. To our knowledge, there are no reports using an MR imaging scoring system to establish practical criteria for prognostic factors of AESD.

The aim of the present study was to score the restricted diffusion areas in patients with AESD to predict their outcomes by qualitative analyses of DWI, and assess the relationships between the anatomical sites of restricted diffusion areas and their outcomes.

Materials and methods

Subjects

According to previous studies of AESD and the acute encephalopathy guideline of the Japanese society of child neurology in 2016, the inclusion criteria were determined as follows: (1) an early seizure within 24 h from onset of fever, (2) subsequent, transient improvement in consciousness, (3) restricted diffusion in the subcortical white matter on DWI during days 3–9, and (4) exclusion of resembling diseases such as other encephalopathy syndromes, encephalitis, and trauma [2, 6–8, 10]. When DWI showed restricted diffusion in the subcortical white matter during days 3–9, a diagnosis of AESD was made even if the patient did not show a late seizure; strong medications such as thiopental can mask late seizures, and late seizures are not absolutely necessary for diagnosis of AESD in the acute encephalopathy guideline of the Japanese society of child neurology in 2016 [10]. Our study was approved by the institutional review board of our institution, which waived the informed consent because this was an observational study.

From January 2011 to March 2018, 45 patients were diagnosed with AESD by one of four pediatricians (IK, SO, KA, MT, 17 years, 23 years, 25 years, and 35 years of pediatrics experience, respectively) in our institution. According to electronic medical records, a final 30 patients fulfilled the inclusion criteria (21 girls, 9 boys; mean age, 16.9 months; age range 4–56 months).

Clinical assessments

We retrospectively reviewed age of onset, sex, presence of biphasic seizures, and neurological outcomes of the patients according to electronic medical records. When a late seizure occurred during day 4–6, biphasic seizures were considered present. Neurological outcomes were assessed at 1 year after onset of AESD by one of the four pediatricians. At this time, patients were classified into two groups as follows: severe group, when patients could not speak meaningful words or could not sit without support; non-severe group, when patients could speak meaningful words and could sit without support.

Treatments

We retrospectively reviewed treatments of the patients during the acute phase. All of the 30 patients received supportive treatment including administration of anticonvulsants. Five of the 30 patients received therapeutic hypothermia. Eleven of the 30 patients received steroid pulse therapy. Five of the 30 patients received intravenous immunoglobulin. We excluded treatment data from statistical analysis, because the treatment guidelines for AESD were not well established.

MR imaging examinations and assessments

All patients received MR imaging during days 3–9. Twenty-eight of the 30 patients received MR imaging examination only once and the other two patients received several examinations during days 3–9. MR imaging of both the two patients revealed abnormalities only in each latest examination during days 3–9. So, the latest examination was assessed.

Twenty-two of the 30 patients were scanned in our institution, while eight were scanned in other institutions. Eight of the 30 patients also received MR imaging on days 1–2. Several MR scanners were used, including a Skyra (3 T; Siemens, Erlangen, Germany), Symphony and Aera (1.5 T; Siemens), Achieva and Intera (1.5 T; Philips Medical Systems, Best, Netherlands), and Signa (1.5 T; GE Healthcare, Milwaukee, WI, USA). DWI was performed in all examinations using the following imaging parameters: axial image, echo-planar imaging sequence, b-values = 0 and 1000 s/mm^2, repetition time = 2598–8229 ms, echo time = 67–110 ms, flip angle = 90°, field of view = 190–230 × 200–279 mm, matrix = 96–160 × 86–128, slice thickness = 2.5–6.0 mm. ADC maps were calculated by the software of the MR scanners, except for one case where ADC map was calculated using OsiriX (Pixmeo, Geneva, Switzerland, https://www.osirixviewer.com/).

Two radiologists (HT, TM, 5 and 37 years, neuroradiology experience, respectively) blinded to the clinical information of patients evaluated the DWI retrospectively and independently. We defined lesions as hyperintense areas on DWI with low ADC values compared with the brainstem, because no brainstem abnormalities were revealed in this study. The locations of the lesions were classified as follows: frontal lobes (except precentral gyri), parieto-occipital lobes (except postcentral gyri), temporal lobes,

perirolandic areas (precentral and postcentral gyri), basal ganglia, thalamus, corpus callosum, cerebellum, and brainstem, to assess the locations in more detail than that previously reported [7]. Except for the corpus callosum and brainstem, we counted these locations separately on the right and left. We defined the parietal and occipital lobes as one site because it was difficult to distinguish parietal lobes from the occipital lobes in axial images. When discrepancy occurred between the two radiologists, their assessments were discussed until a consensus was reached. There were no images with severe artifacts that affected their evaluation.

We established a DWI scoring system as follows: zero for normal, and one for lesions at each location. Basal ganglia, thalamic, corpus callosum, brainstem, and cerebellar lesions were excluded from this scoring system to avoid overestimation by the secondary neuronal degeneration [11–15]. The total score was calculated by adding each score (maximum score eight).

Statistical analyses

Statistical analyses of differences between the severe group and the non-severe group were performed. Fisher's exact probability test was used for sex, presence of biphasic seizures, each lesion location, and lesion laterality. Mann–Whitney *U* test was used for age of onset and the total score. *P* values < 0.05 were considered statistically significant. Receiver operating characteristic (ROC) curve was plotted to estimate the sensitivity and the specificity of the total scores and to determine the cutoff values. Cohen's kappa coefficient was calculated to assess the interobserver variability between the two radiologists. All statistical analyses were performed using EZR version 1.35 (Saitama Medical Center, Jichi Medical University, Saitama, Japan) [16].

Results

Clinical findings

Of the 30 patients, nine (30%) were classified into the severe group and 21 (70%) into the non-severe group. In the severe group, the mean age of onset was 19.6 months, there were five boys and four girls, and biphasic seizures occurred in eight (88.9%) of the nine patients. In the non-severe group, the mean age of onset was 15.8 months, there were four boys and 17 girls, and biphasic seizures occurred in 18 (85.7%) of the 21 patients. The age of onset ($P = 0.55$), sex ($P = 0.08$), and presence of biphasic seizures ($P = 1.0$) were similar between the two groups. No patients had any lesions on MR imaging during days 1–2. The clinical information and MR imaging findings on days 1–2 of the severe group and the non-severe group are shown in Tables 1 and 2 respectively.

MR imaging findings

The clinical and DWI (during days 3–9) findings are summarized in Table 3. The DWI scoring system findings of the severe group and the non-severe group are summarized in Tables 4 and 5, respectively.

In the severe group, MR imaging during days 3–9 showed nine of the nine patients (100%) with frontal lobe lesions, nine (100%) with parieto-occipital lobe lesions, eight

Table 1 Summary of the severe group of patients with AESD

No.	Age (months)	Sex	Biphasic seizures	MR imaging during day 1–2	Motor impairment	Speech impairment
1	24	Female	+	N/A	−	+
2	18	Female	+	N/A	−	+
3	12	Female	+	N/A	+	+
4	6	Female	+	N/A	−	+
5	4	Male	+	Normal	−	+
6	56	Male	−	N/A	−	+
7	13	Male	+	Normal	+	+
8	29	Male	+	Normal	+	+
9	14	Male	+	N/A	+	+

AESD acute encephalopathy with biphasic seizures and late reduced diffusion

MR magnetic resonance

N/A not applicable

Table 2 Summary of the non-severe group of patients with AESD

No.	Age (months)	Sex	Biphasic seizures	MR imaging during day 1–2	Motor impairment	Speech impairment
10	12	Female	+	N/A	–	–
11	24	Female	–	N/A	–	–
12	9	Female	+	N/A	–	–
13	16	Female	+	N/A	–	–
14	10	Female	+	Normal	–	–
15	12	Female	+	N/A	–	–
16	16	Male	+	N/A	–	–
17	16	Female	+	N/A	–	–
18	11	Female	+	N/A	–	–
19	14	Female	+	N/A	–	–
20	9	Female	+	N/A	–	–
21	22	Female	+	N/A	–	–
22	18	Female	+	N/A	–	–
23	4	Female	+	Normal	–	–
24	8	Male	+	Normal	–	–
25	13	Female	–	Normal	–	–
26	15	Male	+	N/A	–	–
27	47	Female	–	Normal	–	–
28	9	Male	+	N/A	–	–
29	9	Female	+	N/A	–	–
30	37	Female	+	N/A	–	–

AESD acute encephalopathy with biphasic seizures and late reduced diffusion

MR magnetic resonance

N/A not applicable

(88.9%) with temporal lobe lesions, six (66.7%) with perirolandic lesions, two (22.2%) with thalamic lesions, and six (66.7%) with corpus callosum lesions. In the non-severe group, MR imaging during days 3–9 showed 21 of the 21 patients (100%) with frontal lobe lesions, 14 (66.7%) with parieto-occipital lobe lesions, seven (33.3%) with temporal lobe lesions, three (14.3%) with perirolandic lesions, three (14.3%) with thalamic lesions, and one (4.8%) with a corpus callosum lesion. Patients in the severe group were more likely to have temporal lobe lesions ($P=0.014$), perirolandic lesions ($P=0.008$), and corpus callosum lesions ($P=0.0008$) than those in the non-severe group. There were no differences in the rates of frontal lobe lesions ($P=1.0$), parieto-occipital lobe lesions ($P=0.07$), or thalamic lesions ($P=0.62$) between the two groups. No patients showed lesions in the basal ganglia, cerebellum, or brainstem in either group.

Among all 30 patients, nine (30%) patients had completely unilateral hemisphere lesions and the other 21 (70%) had bilateral hemisphere lesions including asymmetric lesions. Among the nine patients with completely unilateral hemisphere lesions, one (11.1%) patient belonged to the severe group and the other eight (88.9%) patients belonged to the non-severe group. Among the 21 patients with bilateral hemisphere lesions including asymmetric lesions, eight (38.1%) patients belonged to the severe group, and the other 13 (61.9%) patients belonged to the non-severe group. There was no statistically significant difference in neurological outcomes between the patients with completely unilateral lesions and bilateral hemisphere lesions including asymmetric lesions ($P=0.21$). Among the nine patients with completely unilateral hemisphere lesions, four (44%) patients had completely left unilateral lesions and the other five (56%) had completely right unilateral lesions. Among the four patients with completely left unilateral lesions, one

Table 3 Comparison of clinical and DWI findings (performed during days 3–9) between the severe and non-severe groups

	Severe group ($n=9$)	Non-severe group ($n=21$)	P value
Clinical findings			
Age at onset (months), range (mean)	4–56 (19.6)	4–47 (15.8)	0.55
Sex, male:female	5:4	4:17	0.08
Biphasic seizures	8	18	1.0
DWI findings during days 3–9			
Frotnal lobes	9 (100%)	21 (100%)	1.0
Parieto-occipital lobes	9 (100%)	14 (66.7%)	0.07
Temporal lobes	8 (88.9%)	7 (33.3%)	0.014
Perirolandic areas	6 (66.7%)	3 (14.3%)	0.008*
Thalamus	2 (22.2%)	3 (14.3%)	0.62
Basal ganglia	0	0	N/A
Corpus callosum	6 (66.7%)	1 (4.8%)	0.0008*
Cerebellum	0	0	N/A
Brainstem	0	0	N/A

DWI diffusion-weighted imaging

N/A not applicable

*$P<0.05$

(25%) patient belonged in the severe group and the other three (75%) belonged in the non-severe group. Among the five patients with completely right unilateral lesions, all of them belonged to the non-severe group. There was no statistically significant difference in neurological outcomes between the patients with completely left unilateral lesions and completely right unilateral lesions ($P=0.44$).

Representative cases from the severe group (Fig. 1) and the non-severe group (Fig. 2, 3) were presented.

In the DWI scoring system, the total scores of patients in the severe group were significantly higher than those in the non-severe group ($P=0.0002$). The DWI scoring system findings of the severe group and the non-severe group are summarized in Table 4, 5**,** respectively. The area under the curve was 0.929 (95% confidence interval, 0.82–1.0). When the cutoff value was five, the sensitivity was 88.9% and the specificity was 81.0%. The total scores and the ROC curve are shown in Fig. 4. The Cohen's kappa coefficient between the two radiologists was 0.89 (95% confidence interval 0.83–0.95), indicating excellent agreement.

Discussion

In the present study, there were no differences in clinical findings, including age of onset, sex, and presence of biphasic seizures, between patients with severe and non-severe AESD. In addition, DWI findings showed that all patients with both severe and non-severe AESD had frontal lobe lesions, and there were no differences in parieto-occipital lobe lesions and lesion laterality between patients with severe and non-severe AESD. However, DWI findings showed that patients with severe AESD were more likely to have more extensive lesions than patients with non-severe AESD. In fact, total DWI scores were significantly higher

Table 4 Summary of DWI scoring system findings in the severe group of patients with AESD

No.	Frontal lobes		Parieto-occipital lobes		Temporal lobes		Perirolandic areas		Score
	Right	Left	Right	Left	Right	Left	Right	Left	
1	−	+	−	+	−	+	−	−	3
2	+	+	+	+	+	+	+	+	8
3	+	+	+	+	+	+	+	+	8
4	+	+	+	+	+	−	−	−	5
5	+	+	+	+	+	+	+	+	8
6	+	+	+	+	+	+	−	−	6
7	+	+	+	+	+	+	+	+	8
8	+	+	+	+	+	+	+	−	7
9	+	+	+	+	−	−	+	+	6

DWI diffusion-weighted imaging

AESD acute encephalopathy with biphasic seizures and late reduced diffusion

Table 5 Summary of DWI scoring system findings in the non-severe group of patients with AESD

No.	Frontal lobes		Parieto-occipital lobes		Temporal lobes		Perirolandic areas		Score
	Right	Left	Right	Left	Right	Left	Right	Left	
10	+	−	−	−	−	−	−	−	1
11	+	+	+	+	+	+	−	−	6
12	+	+	−	−	−	−	−	−	2
13	−	+	−	+	−	+	−	−	3
14	+	+	+	+	−	+	−	−	5
15	+	−	+	−	+	−	−	−	3
16	+	+	−	−	−	−	−	−	2
17	+	−	+	−	+	−	+	−	4
18	+	+	−	−	−	−	−	−	2
19	+	+	−	+	−	−	−	−	3
20	+	+	−	+	−	−	−	−	3
21	−	+	−	+	−	+	−	−	3
22	+	+	−	−	−	−	−	−	2
23	+	+	+	+	−	−	+	−	5
24	+	+	+	+	−	−	−	−	4
25	+	+	−	−	−	−	−	−	2
26	+	−	−	−	−	−	−	−	1
27	+	+	+	+	−	+	−	−	5
28	−	+	−	+	−	−	−	−	2
29	+	−	+	−-	−	−	+	−	3
30	+	+	+	+	−	−	−	−	4

DWI diffusion-weighted imaging

AESD acute encephalopathy with biphasic seizures and late reduced diffusion

in patients with severe AESD, indicating more widespread DWI abnormalities. Further, ROC analysis showed a high area under the curve and, with an appropriate cutoff value of five, the DWI scoring system showed a high sensitivity and specificity.

In our DWI scoring system, we excluded basal ganglia, thalamic, and corpus callosum lesions. Kurahashi et al. [11] reported that the thalamus restricted diffusion in patients with AESD, which was associated with subcortical or cortical lesions through the thalamocortical tract. Though not AESD, Okabe et al. [12] reported that thalamic and corpus callosum-restricted diffusion was seen in neonates and infants with acute middle cerebral artery cortical infarction because of the acute network injury. Kamiya et al. [13] also reported that the restricted diffusion was observed in basal ganglia and thalamus after cerebral surgery. In addition, Uchino et al. [14] reported that the restricted diffusion was observed in the brainstem as Wallerian degeneration after acute posterior limb of internal capsule infarction, and Samaniego et al. [15] reported that the restricted diffusion was observed in the cerebellum as crossed cerebellar diaschisis after status epilepticus. Therefore, we considered that basal ganglia, thalamic, corpus callosum, brainstem, and cerebellar lesions in patients with AESD might be caused by secondary neuronal degeneration, and we excluded those lesions from the DWI scoring system to avoid overestimation.

On DWI in our study results, among more extensive lesions except frontal lobe and parieto-occipital lobe lesions, patients with severe AESD were more likely to have temporal lobe, perirolandic, and corpus callosum lesions than patients with non-severe AESD. In fact, all patients with severe AESD ($n=9$) could not speak meaningful words. The temporal lobes are important for language function, and several studies have also reported that the splenium of the corpus callosum has an important role in orienting to salient information and supporting acquisition of spoken language during infancy [17–19]. In our study, seven of all 30 patients had corpus callosum lesions including splenium, and all of the seven patients also had temporal lobe lesions. Association fibers in the splenium of corpus callosum are connected

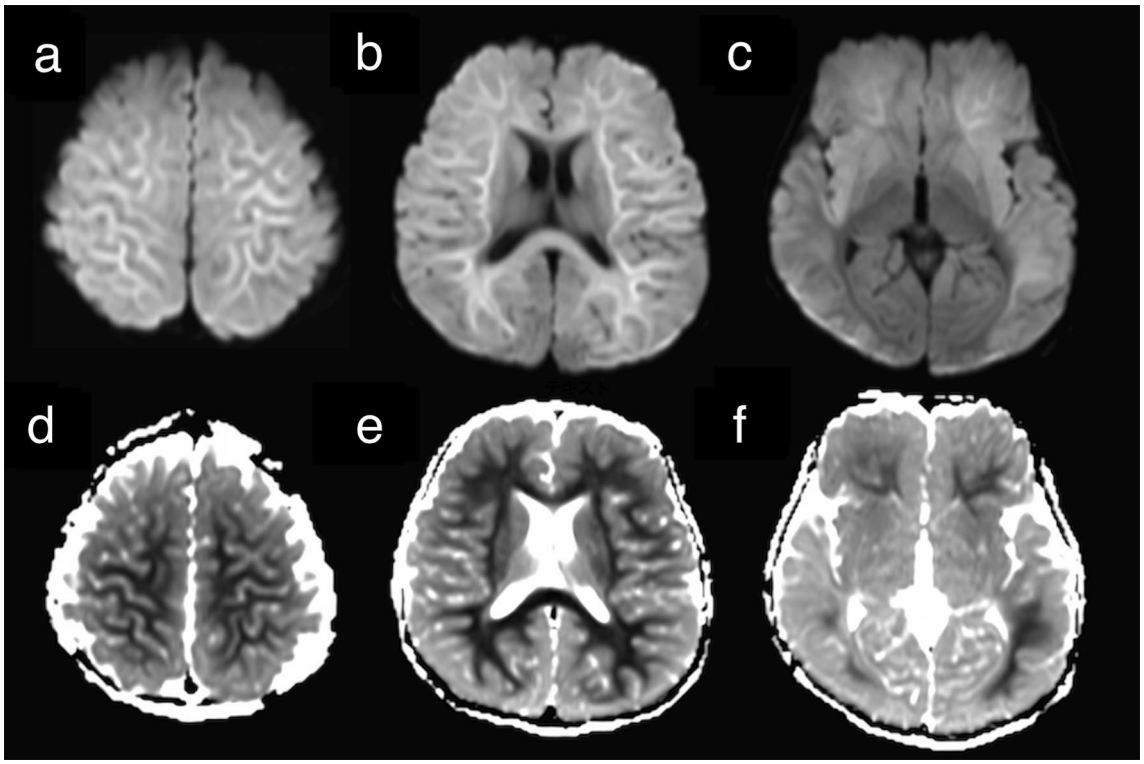

Fig. 1 A 13 month-old boy (patient No. 7 in Table 1) in the severe group scanned on day 7. **a–c** Diffusion-weighted imaging (DWI). **d–f** Apparent diffusion coefficient (ADC) maps at the same level as **(a–c)**. Restricted diffusion (hyperintensity on DWI, hypointensity on ADC maps) can be seen in both frontal lobes, both parietal lobes, both perirolandic areas, both temporal lobes, and the corpus callosum. Total DWI score was eight

between the left and right temporal lobes. Therefore, we think that the corpus callosum lesions including splenium might be secondary neuronal degeneration caused by temporal lobe lesions, which contribute to the impairment of language function. In addition, four (44.4%) of the nine patients with severe AESD could not sit without support, and all of these patients showed perirolandic lesions. Okumura et al. [20] reported that the neurological outcomes of acute encephalopathy patients with diffuse lesions in the subcortical white matter on DWI were worse than those without perirolandic lesions. Although this report included patients with acute encephalopathy except for AESD, this result was similar to our results. Thus, the restricted diffusion in the perirolandic areas may contribute to the impairment of motor function.

As described above, we considered separately the relationships between neurological deficits and each lesion location. However, it may not be appropiate to consider separately the relationships between neurological outcomes and each lesion location, because brain function is complex and more widespread lesions seemed to have stronger influence on neurological outcomes than each lesion location. In the DWI scoring system results, all patients with only frontal lobe lesions ($n=7$ of 30, 23.3%) and both frontal lobe and parieto-occipital lobe lesions ($n=5$ of 30, 16.7%) were found only in the non-severe group. However, all of the nine patients in the severe group showed additional other lesions with both frontal lobe and parieto-occipital lobe lesions. Thus, our results suggested that the neurological outcomes of the patients with other lesions in addition to frontal lobe and parieto-occipital lobe tended to become severe. Takanashi et al. [3] reported that the AESD patients with only frontal lobe lesions fully recovered without neurological sequelae. Furthermore, Yamanouchi et al. [21] advocated acute infantile encephalopathy predominantly affecting the frontal lobes, which is now considered as a mild form of AESD [22, 23]. Our results were similar to these reports.

In our results, when the scores were five and more, the neurological outcomes tended to become severe. Among the patients with completely unilateral hemisphere lesions

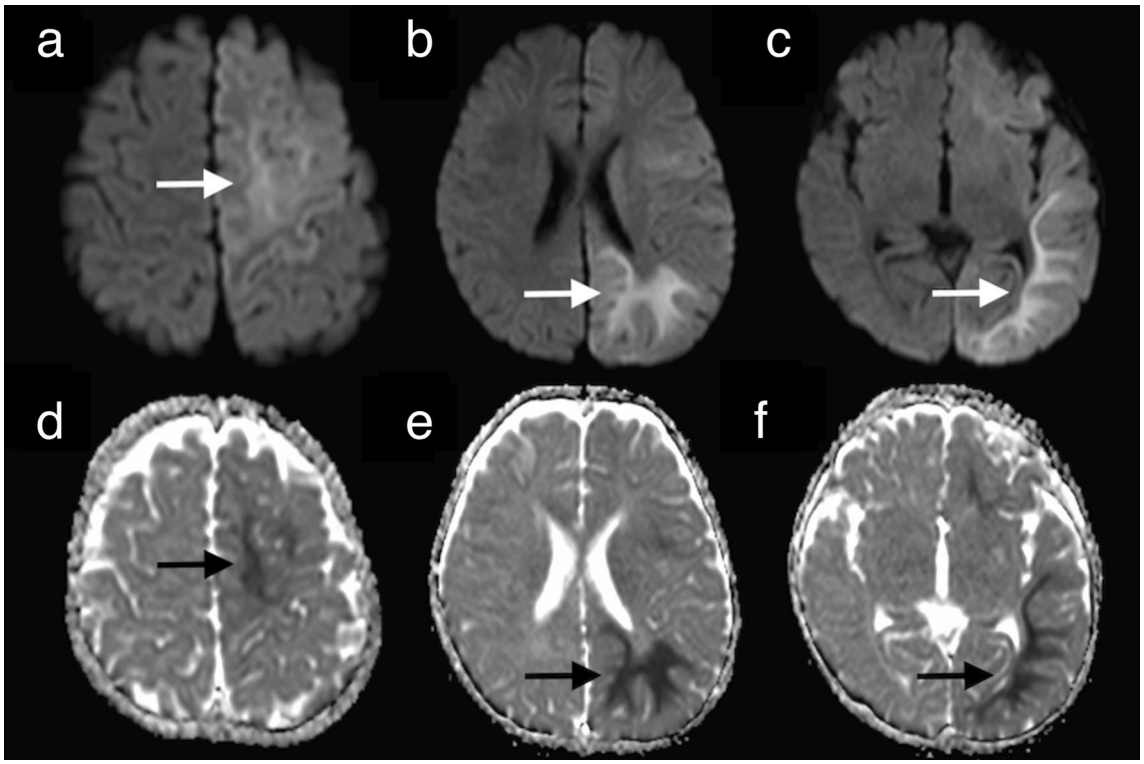

Fig. 2 A 16 month-old girl (patient no.13 in Table 2) in the non-severe group scanned on day 7. **a–c** DWI. **d–f** ADC maps at the same level as **(a–c)**. Restricted diffusion (hyperintensity on DWI, hypointensity on ADC maps) can be seen in the left frontal lobe (arrows), left parietal lobe (arrows), and left temporal lobe (arrows). Total DWI score was three

($n=9$), eight (88.9%) of the nine patients were in the non-severe group, and all of the scores of the patients with completely unilateral hemisphere lesions were four or less. It is known that the developing brain shows a plasticity, and language and motor function often recover well following early brain unilateral injury [24–26]. Therefore, we considered that the neurological outcomes of the patients with completely unilateral hemisphere lesions tended to become non-severe. However, our study results showed no significant difference ($P=0.21$) between the neurological outcomes of the patients with bilateral hemisphere lesions including asymmetric lesions and completely unilateral hemisphere lesions. We think this lack of significant difference may be attributable to a small sample size.

In the present study, there were no patients with basal ganglia lesions. This contrasts with the report of Lee et al. [7], in which nine of 18 patients with AESD had restricted diffusion areas in the basal ganglia on MR imaging. In that study, the authors used ADC maps to measure the extent of the lesions with reduced diffusion in each brain region, which were manually segmented into the anterior cerebrum, posterior cerebrum, basal ganglia, thalamus, and cerebellum and brainstem. Importantly, their schema showed that the area defined as the basal ganglia included the anterior and posterior limb of the internal capsule, and the external capsule. By contrast, our definition of the basal ganglia did not include the anterior and posterior limb of internal capsule, or the external capsule, which may be the reason for the discrepancies between these studies.

There were three limitations in this study. First, DWI was performed by several institutions, with different imaging parameters. However, the b-values were identical and we thought the various slice thickness (2.5–6.0 mm) did not affect the evaluation of DWI because the lesions were much larger. Second, this was a retrospective study and the follow-up period is only 1 year, which seemed to be insufficient to conclude about the neurological outcomes. Although the follow-up periods of most other previous studies about prognostic factors of AESD and similar acute infantile encephalopathy were about one year [6, 7, 11], a longer follow-up period is warranted to evaluate higher brain dysfunction including intellectual impairment and visual impairment. Third, we did not evaluate the effect of treatments. Because none of the special treatments for AESD such as cerebral hypothermia, steroid pulse, and intravenous immunoglobulin had sufficient evidence [10]. In addition, the later effect of the treatments has not been revealed well in several other previous studies about prognostic factors of AESD [1, 7, 11].

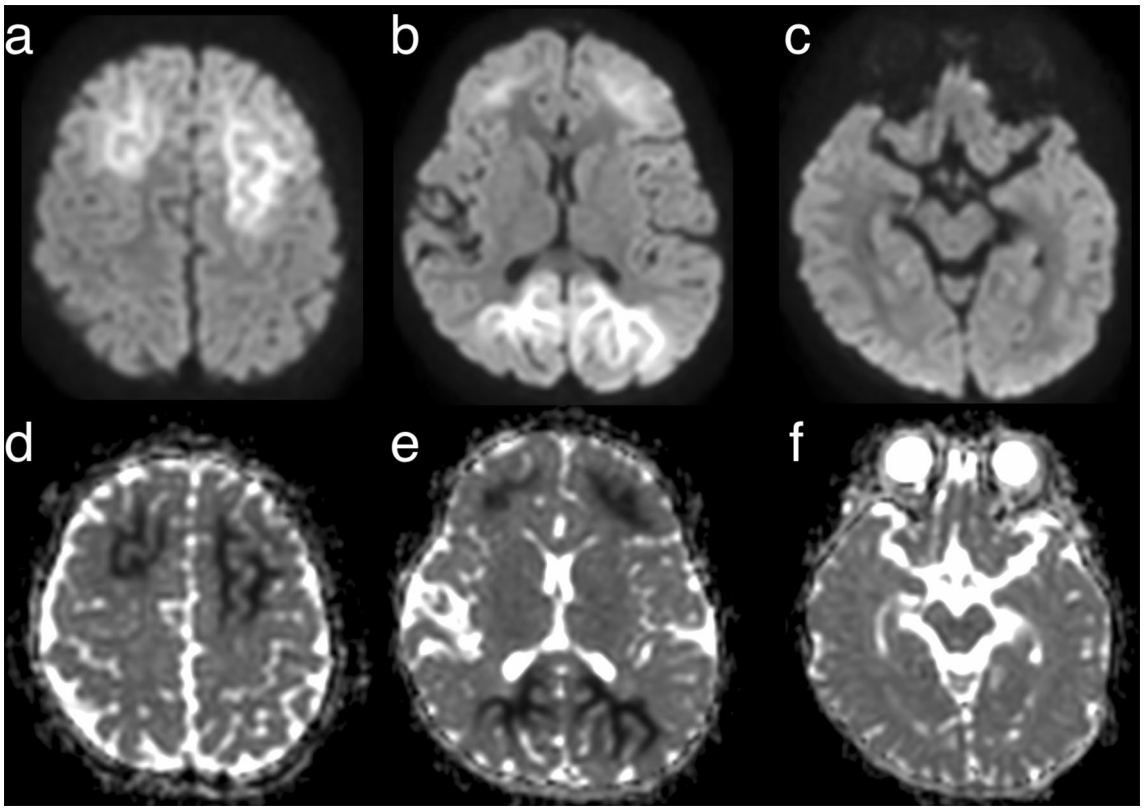

Fig. 3 A 37 month-old girl (patient no.30 in Table 2) in the non-severe group scanned on day 5. **a–c** DWI. **d–f** ADC maps at the same level as **(a–c)**. Restricted diffusion (hyperintensity on DWI, hypointensity on ADC maps) can be seen in both frontal lobes and both parieto-occipital lobes. Total DWI score was four

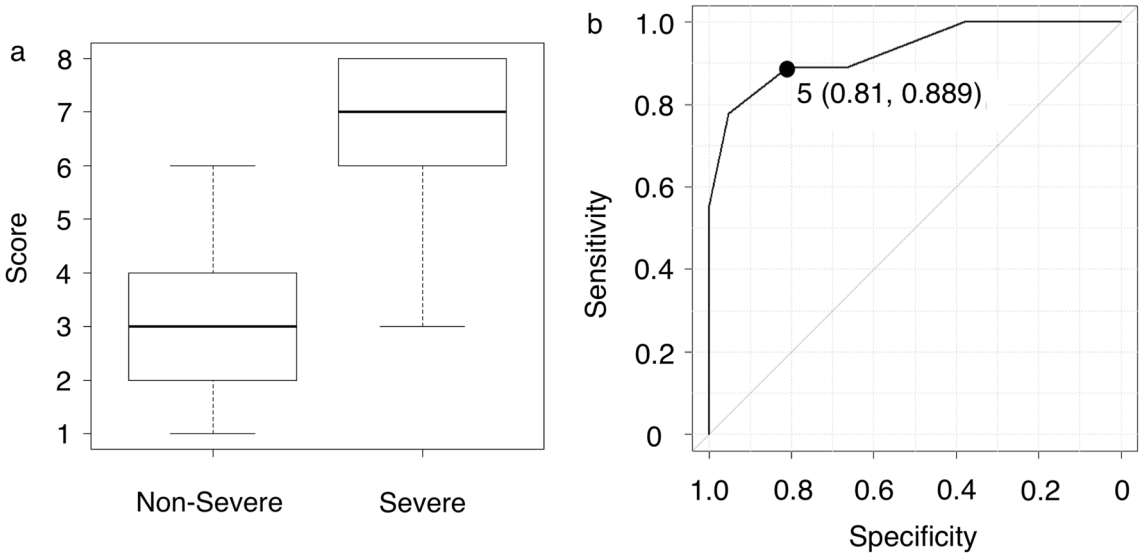

Fig. 4 Graphs of statistical analyses. **a** Box-plot of the DWI scoring system of score between the severe group and the non-severe group. Left box shows the total score in the non-severe group (maximum six, upper quartile four, median three, lower quartile two, minimum one). Right box shows the total score in the severe group (maximum eight, upper quartile eight, median seven, lower quartile six, minimum three). The total scores of in the severe group were significantly higher than those in the non-severe group ($P=0.0002$). **b** Receiver operating characteristic curve to estimate the sensitivity and the specificity of the total scores and determine the cutoff values. The area under the curve was 0.929 (95% confidence interval, 0.82–1.0). When the cutoff of the total score was five, the sensitivity was 88.9% and the specificity was 81.0%

Conclusion

Patients with severe AESD had more extensive DWI abnormalities than those with non-severe AESD, and the DWI scoring system may be useful for the prediction of outcomes of AESD. Widespread lesions seemed to have stronger influence on outcomes than each lesion location.

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Compliance with ethical standards

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

Ethical statement This article does not contain any studies with human participants or animals performed by any of the authors.

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