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ORIGINAL ARTICLE

Neurological manifestations and neuroimaging presentations in patients with severe preeclampsia: predisposing factors and clinical implications

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Abstract

Background and purpose Neurological manifestations and neuroimaging abnormalities are common in patients with severe preeclampsia; however, the differences between these abnormal features occurring during early- and late-onset severe preeclampsia are unclear, and the factors associated with abnormal imaging changes in patients with neurological manifestations have not yet been fully elucidated.

Materials and methods A retrospective study was conducted on 172 patients with severe preeclampsia from January 2017 to June 2018 in the Department of Neurology and Obstetrics, Shengjing Hospital of China Medical University. The neurological manifestations, clinical parameters, laboratory, and neuroimaging findings were analyzed.

Results Early- and late-onset preeclampsia were diagnosed in 83 and 89 patients, respectively. Headache and dizziness were more common in patients with early-onset preeclampsia than in patients with late-onset preeclampsia ($p = 0.013$, $p = 0.004$, respectively). Serum uric acid, creatinine, and urea nitrogen were significantly elevated in the patients with early-onset preeclampsia ($p < 0.001$, $p = 0.004$, and $p = 0.005$, respectively). Neuroimaging was performed in 81 patients, of which 57 were positive. Findings indicating cerebral edema were the most common neuroimaging abnormality. Gestational weeks ($p = 0.014$), headache ($p < 0.001$), and blood urea nitrogen level ($p = 0.027$) may be associated with positive imaging findings. By multiple logistic regression, headache (OR = 10.2, 95% CI, 2.4–42.7; $p = 0.002$) proved to be an independent factor associated with neuroimaging abnormality.

Conclusions Neurological symptoms such as headache and dizziness were more common in patients with early-onset preeclampsia. Renal dysfunction may also associate with early-onset severe preeclampsia. Cerebral edema was the most common neuroimaging abnormality, and headache might be independently associated with abnormal imagine changes.

Keywords Preeclampsia · Renal functions · Headache · Neuroimaging

Introduction

A growing number of studies have confirmed that pregnancy with neurological complications can pose a serious threat to maternal and fetal morbidity and mortality, and these manifestations are most common in patients with preeclampsia and eclampsia [1, 2]. Common neurological signs and symptoms include dizziness, headache, visual abnormalities, epilepsy, disturbance of consciousness, and limb paralysis [3]. The early identification of neurological manifestations and early diagnosis of neurological complications are essential for improving patient outcomes and avoiding fetal complications [4].

Preeclampsia, which affects about 5% of pregnant women [5], refers to the occurrence of elevated blood pressure and proteinuria in the mother after 20 weeks of pregnancy, with or without headache, dizziness, nausea, vomiting, epigastric discomfort, and other signs and symptoms. Severe preeclampsia is diagnosed in patients with preeclampsia accompanied by elevated blood pressure, increased urinary protein level, impaired renal function, decreased platelet level, and microvascular hemolysis [6]. Depending on the time of occurrence, severe preeclampsia occurring before 34 weeks of gestation

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is clinically defined as early-onset type, while after 34 weeks is defined as later-onset type [7]. Because of the different pathogenesis between these two types, the neurological complications might be also different; however, previous studies have focused on the neurological complications of patients with preeclampsia, but research on comparing the neurological complications of patients with early-onset versus those of patients with late-onset preeclampsia is lacking [8].

The diagnostic value of neuroimaging for neurological diseases is self-evident, but the use of neuroimaging in pregnant patients has been criticized because of the possible risk that computed tomography (CT) poses to the fetus. However, with ongoing improvements in magnetic resonance imaging (MRI), modality has now become widely used in pregnant patients and has greatly raised detection rate [9]. However, there are still no uniform standards for selecting the imaging methods for different neurological manifestations. Moreover, the clinical factors affecting imaging results are still controversial.

This study retrospectively analyzed and summarized the clinical data of 172 patients with severe preeclampsia, and the imaging results of 81 of the study patients were recorded and compared. We elaborated on the differences between the neurological complications and results of laboratory examinations occurring in patients with early- and late-onset severe preeclampsia, and further analyzed the factors that might be associated with positive imaging results, with the intention of providing information to clinicians that furthers their understanding of neurological complications and enables their selection of neuroimaging modalities for evaluating patients with severe preeclampsia.

Methods

Patients and study protocol

This was a single-center retrospective study that was performed at Shengjing Hospital of China Medical University from January 2017 to June 2018. The data from 172 patients with severe preeclampsia were collected from the Department of Neurology and Obstetrics of the hospital. Severe preeclampsia was diagnosed based on the criteria established by the American College of Obstetrics and Gynecology [10]. The onset of severe eclampsia before 34 weeks of gestation was considered to be early preeclampsia, and the onset at 34 weeks of gestation or later was considered to be late preeclampsia [11]. Patients with severe preeclampsia were included in the study if they also satisfied the following conditions: (1) showed acute or subacute onset of at least 1 neurological symptoms, such as severe headache, dizziness, visual disturbance, hemiplegia, hemidysesthesia, or impaired consciousness; and (2) received cranial neuroimaging examinations, including CT, MRI, magnetic resonance angiography (MRA), or magnetic resonance venography (MRV) within 48 h of sign/symptom onset. Patients with one of the following conditions were excluded: (1) history of central nervous system lesions, such as cerebral infarction, cerebral hemorrhage, intracranial vascular malformation, neurodegenerative disease, or epilepsy; (2) history of primary hypertension, severe heart disease, liver and kidney dysfunction, infectious disease, autoimmune rheumatic disease, or hematological disease.

The collected clinical parameters included the following: patient age, time of diagnosis in gestational weeks, and blood pressure (BP). BP was recorded at the onset of neurological symptoms, and mean blood pressure (MBP) was calculated as (systolic BP + 2 × diastolic BP)/3. The following laboratory data were collected: white blood cell count and percent neutrophils; platelet count; and serum levels of hemoglobin, alanine transaminase, aspartate transaminase, urea nitrogen, and D-dimers.

Neuroimaging

CT scans were performed by a 256-layer multislice CT scanner (Philips Healthcare, Amsterdam, The Netherlands), with 120 kV tube voltage, 204 mAs tube current, pitch 0.9, thickness 3 mm, interval 3 mm, matrix 512 × 512, and field of view (FOV) 500 mm × 500 mm. MRI examinations were performed with an Achieva 3.0 Tesla scanner (Philips Healthcare), equipped with an eight-channel phased-array coil for brain imaging. The standard protocol included axial T1- and T2-weighted imaging (T1WI, T2WI), fluid-attenuated inversion recovery (FLAIR) images, and diffusion-weighted imaging (DWI). Time-of-flight MRA or MRV was performed as follows: repetition time 17 ms, echo time 6.23 ms, flip angle 25° (20°), FOV 260 mm, matrix 256 × 256, and slice thickness 0.9 mm.

Neuroimaging was considered positive if the participant's initial CT or MRI findings included cerebral edema, cerebral infarction, cerebral hemorrhage, subarachnoid hemorrhage, cerebral venous thrombosis, or cavernous hemangioma. Participants were classified as "neuroimaging negative" if none of the listed findings were reported.

The main imaging manifestations of cerebral edema consisted of bilateral symmetrical changes seen in the parietal and occipital cortex or subcortical changes. CT manifestations consisted of multiple bilateral patchy hypointensity images, and MRI manifestations consisted of hyperintensity on T2WI or FLAIR sequences and hypointensity on T1WI sequences. Two neuroimaging physicians blinded to the clinical data interpreted all the neuroimaging studies and reached a consensus for assessments on which they disagreed.

Statistical analysis

Statistical analysis was performed by standard software (SPSS v17.0, SPSS Inc. [IBM], Chicago, IL, USA), with statistical significance set at $p < 0.05$. Continuous variables were expressed as means ± SD, and discrete data were expressed as frequencies and percentages. The Student *t* test was used for continuous variables, and the Fisher exact test was used for discrete variables. A forward stepwise variable selection method of multivariate analysis was applied to calculate odds ratios (ORs) and corresponding 95% confidence intervals (CIs) for factors related to positive neuroimaging results.

Results

Clinical characterizations

This study enrolled 172 patients with severe preeclampsia. Their mean age was 32.3 ± 5.3 years, and mean number of gestational weeks at diagnosis was 32.1 ± 5.1 weeks. The spectrum of neurological signs and symptoms included dizziness (99/172, 57.6%), headache (91/172, 52.9%), visual disturbance (49/172, 28.5%), impaired consciousness (11/172, 6.4%), hemiplegia (2/172, 1.2%), and hemidysesthesia (2/172, 1.2%).

Comparison of clinical and laboratory data in patients with early- and late-onset preeclampsia

Among the 172 patients, 83 (48.3%) were diagnosed with early-onset preeclampsia, and 89 patients were diagnosed with late-onset preeclampsia. Table 1 shows the admission clinical and laboratory data of the patients with early- and late-onset preeclampsia.

The frequency of headache and dizziness in the respective patients with early-onset versus late-onset preeclampsia were 62.7% versus 43.8%, ($p = 0.013$) for headache, and 68.7% versus 47.2%, ($p = 0.004$) for dizziness. The hemoglobin level was significantly higher in the patients with early-onset preeclampsia ($p = 0.032$), and the following indicators of renal function: serum uric acid ($p < 0.001$), serum creatinine ($p = 0.004$), and serum urea nitrogen ($p = 0.005$) were significantly higher in the patients with early-onset preeclampsia than in the patients with late-onset preeclampsia.

Demographic profile of patients undergoing brain imaging

In our study, 81 patients received brain imaging, as follows: 31 (38.3%) and 41 (50.6%) of them had CT and MRI only respectively, and 9 (11.1%) patients underwent both CT and MRI. Of the 50 patients who received MRI, 31 had MRA and 12 had MRV.

Among the 81 patients undergoing neuroimaging, 44 (54.3%) had early-onset preeclampsia and 37 (45.7%) had late-onset preeclampsia. Finally, 57 patients had positive neuroimaging results (Fig. 1). The positive neuroimaging findings of the 57 patients included the following: cerebral edema ($n = 30$ cases [52.6%]), cerebral infarction ($n = 9$ [15.8%]), cerebral hemorrhage ($n = 6$ [10.5%]), cerebral venous thrombosis ($n = 5$ [8.8%]), cavernous hemangioma ($n = 5$ [8.8%]), and subarachnoid hemorrhage ($n = 2$ [3.5%]) (Figs. 2 and 3). Cerebral edema was also the most common positive neuroimaging manifestation in both early- and late-onset preeclampsia patients, but the differences in the two patient groups between the rates of neuroimaging-positive manifestations were not significant (Table 2, Fig. 4).

Comparison of clinical and laboratory characteristics of patients with neuroimaging positive and negative findings

To elaborate the factors related to positive neuroimaging results, we compared the clinical characteristics and laboratory results between patients with positive versus those with negative neuroimaging results. We found that the patients with positive neuroimaging results were diagnosed with preeclampsia at lower numbers of gestational weeks ($p = 0.014$), had a higher incidence of headache ($p < 0.001$), and had a higher blood urea nitrogen level ($p = 0.027$) than patients with negative imaging results (Table 3). Multivariate logistic regression analysis identified headache (OR = 10.15, 95% CI 2.42–42.69; $p = 0.002$) as independently associated with positive neuroimaging results (data not shown).

Discussion

Preeclampsia is a unique disease that occurs during pregnancy and is one of the main causes of maternal and perinatal morbidity and mortality [12]. Preeclampsia is affected by many factors, involving many pathogenic factors and multiple organs and systems; but its pathogenesis remains unclear [13]. At present, the disease can be understood as both placental and maternal dysfunction. Various angiogenic, structural, and metabolic pathways are involved in preeclampsia, including placental oxygenation, helical arterial remodeling, immune tolerance at the maternal-fetal interface, and the balance of angiogenic and antiangiogenic factors [14]. Preeclampsia is clinically divided into early-onset and late-onset preeclampsia based on the gestational age at delivery; most study investigators believe that early-onset preeclampsia is related to endogenous placental factors such as abnormal placental

Table 1 Demographic, clinical, and laboratory data in patients with early and late preeclampsia

	All ($n = 172$)	Early preeclampsia ($n = 83$)	Late preeclampsia ($n = 89$)	P value
Age, y (mean ± SD)	32.3 ± 5.3	32.9 ± 5.9	31.7 ± 4.6	0.106
Gestation week at diagnosis, w (mean ± SD)	32.1 ± 5.1	27.9 ± 4.3	36.0 ± 1.6	0.000
SBP (mm Hg)	153.7 ± 22.5	153.3 ± 19.8	154.1 ± 24.8	0.808
DBP (mm Hg)	103.5 ± 17.8	108.9 ± 10.1	98.4 ± 13.3	0.332
MBP (mm Hg)	120.3 ± 14.0	123.7 ± 8.4	117.2 ± 15.5	0.370
Clinical symptoms				
Headache (*N*, %)	91 (52.9)	52 (62.7)	39 (43.8)	0.013
Visual disturbances (*N*, %)	49 (28.5)	24 (28.9)	25 (28.1)	0.905
Dizziness (*N*, %)	99 (57.6)	57 (68.7)	42 (47.2)	0.004
Impaired consciousness (*N*, %)	11 (6.4)	6 (7.2)	5 (5.6)	0.848
Hemiplegia (*N*, %)	2 (1.2)	1 (1.2)	1 (1.1)	0.960
Hemidysesthesia (*N*, %)	2 (1.2)	1 (1.2)	1 (1.1)	0.960
Laboratory data				
WBC (10^9/L)	11.6 ± 4.1	11.3 ± 4.3	11.8 ± 3.9	0.359
Neutrophil percentage (%)	76.5 ± 9.6	75.6 ± 10.4	77.3 ± 8.8	0.242
Plt (10^9/L)	159.6 ± 59.1	152.3 ± 64.6	166.5 ± 53.1	0.116
HB (g/L)	117.1 ± 24.4	117.7 ± 18.9	111.4 ± 19.3	0.032
ALT (U/L)	27.4 ± 51.5	28.4 ± 44.6	26.6 ± 57.4	0.820
AST (U/L)	41.7 ± 65.5	35.1 ± 62.4	47.8 ± 64.4	0.508
Uric acid (μmol/L)	398.3 ± 106.2	431.1 ± 99.2	367.6 ± 103.8	0.000
Creatinine (μmol/L)	62.9 ± 24.9	68.9 ± 30.4	57.6 ± 16.9	0.004
BUN (mmol/L)	5.5 ± 2.6	6.1 ± 2.6	5.1 ± 2.3	0.005
Cystatin C (μg/L)	1.5 ± 1.3	1.8 ± 0.5	1.6 ± 1.8	0.560
DD (μg/L)	1390.4 ± 1700.5	1466.7 ± 2037.5	1319.3 ± 1138.9	0.571

Figures in parentheses are percentages, unless indicated otherwise

SBP systolic blood pressure, *DBP* diastolic blood pressure, *MBP* mean blood pressure, *WBC* white blood cell, *Plt* platelet count, *HB* hemoglobin, *ALT* alanine transaminase, *AST* aspartate transaminase, *BUN* blood urea nitrogen, *DD* D dimmers

morphology or increased release of toxic placental products, while late-onset preeclampsia is related to maternal factors [15].

Early-onset severe preeclampsia has accounted for about 0.9% of cases of pregnancy-induced hypertension [16]. It has become a difficult problem for clinicians because of its early onset, with long duration to full-term pregnancy and rapid development of maternal condition and severe complications [17]. Among the numerous complications, central nervous system (CNS) complications are one of the most common. Moreover, complications involving the CNS change rapidly and progress in severity, which can lead to irreversible damage to the mother and fetus [18]. Previous studies have found that patients with severe preeclampsia often have headache, blurred vision, disturbance of consciousness, and other problems involving the CNS [19]. At the same time, studies have emphasized that these complications involving the CNS may be more common in patients with early-onset severe preeclampsia [7]. In this study, we found that the headache and dizziness in patients with early-onset severe preeclampsia were significantly higher than the incidence in patients with late-onset, which was consistent with the findings of previous studies. However, the differences between the rates of impaired consciousness, hemiplegia, and hemidysesthesia in the two groups were not significant. Headache and dizziness, the most common nonspecific manifestations of CNS disorders, can be affected by many factors. For example, in our study, BP values (including SBP, DBP, and MBP) of patients with early-onset severe preeclampsia were higher than those of patients with late-onset. Elevated BP may be one of the important factors that lead to headache and dizziness in patients with early-onset preeclampsia. Moreover, the levels of corticosteroid-releasing hormone and other hormones in patients with early-onset preeclampsia were reportedly significantly higher than the levels in patients with late-onset [20]. These hormones might aggravate the degree of systemic vasospasm in pregnant women and induce or aggravate headache and dizziness.

Laboratory testing has shown that hemoglobin levels were significantly lower in patients with late-onset preeclampsia than in patients with early-onset, which is in line with the physiological processes of normal pregnancy [21]. However,

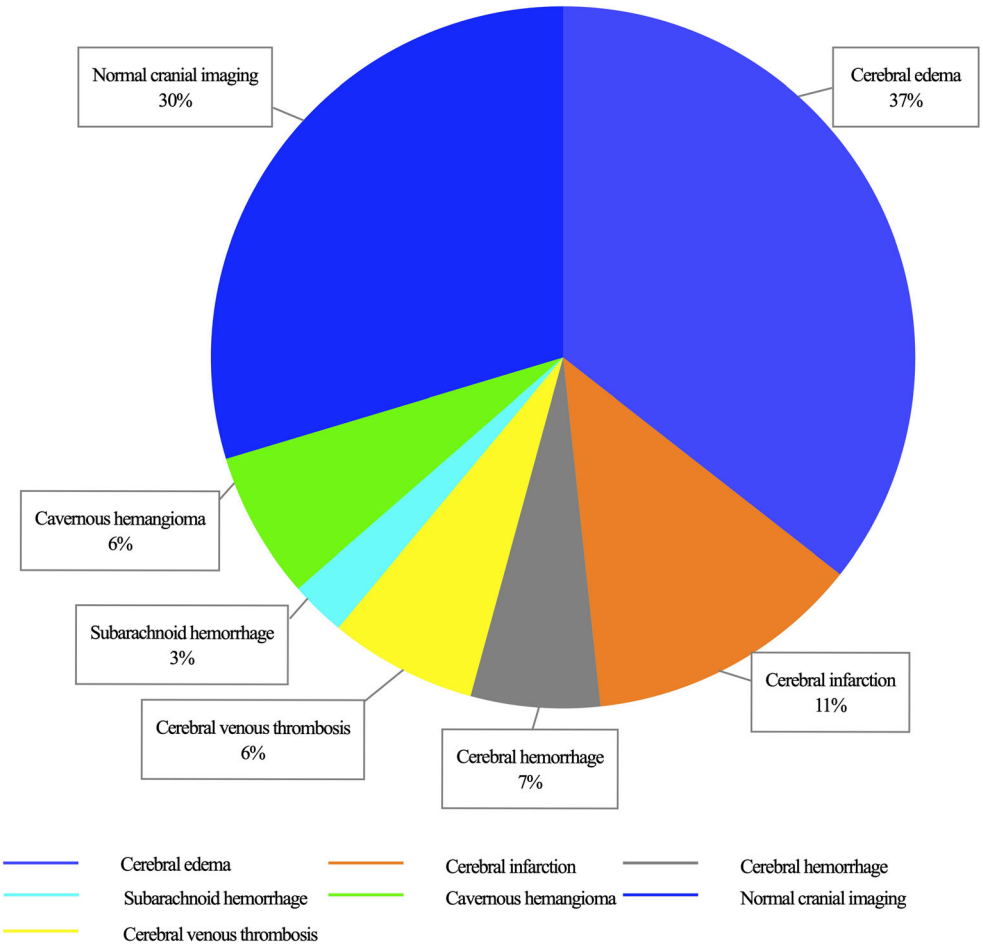

Fig. 1 Neuroimaging findings in preeclamptic patients presenting with neurological signs and symptoms

in our study, the blood levels of uric acid, creatinine, and urea nitrogen, which are indicators of renal function, were significantly increased in patients with early-onset preeclampsia, which is consistent with the conclusions of Li et al. [4]. Li et al. also pointed out that the severity of renal impairment was related to the severity of preeclampsia. Studies such as that of McCartney et al. have also suggested that renal insufficiency is associated with hypertension and changes in osmotic pressure in patients with preeclampsia [22]. In conclusion, signs and symptoms associated with the CNS are more common in

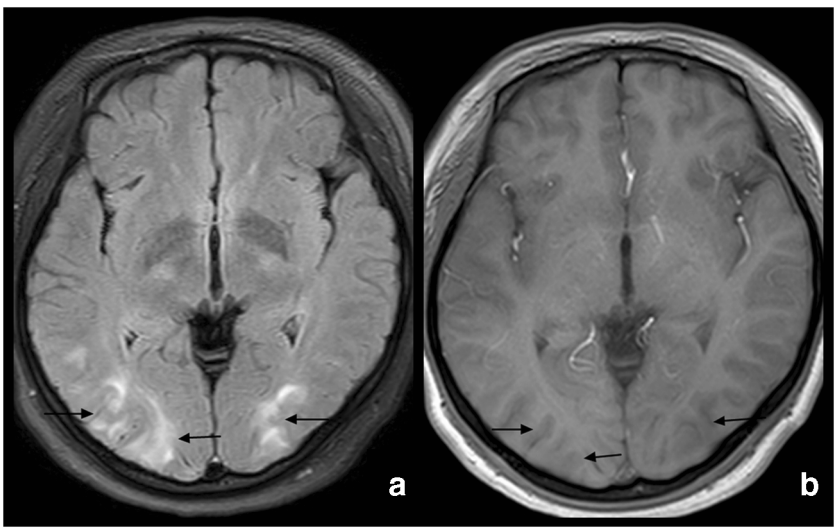

Fig. 2 Cerebral edema on MRI in a patient with severe preeclampsia patient. A 23-year-old patient, 33+ weeks pregnant, with blurred vision and headache. **a** Arrows show bilateral occipital hyperintensities on FLAIR; **b** T1-weighted image shows hypointensities in the same location

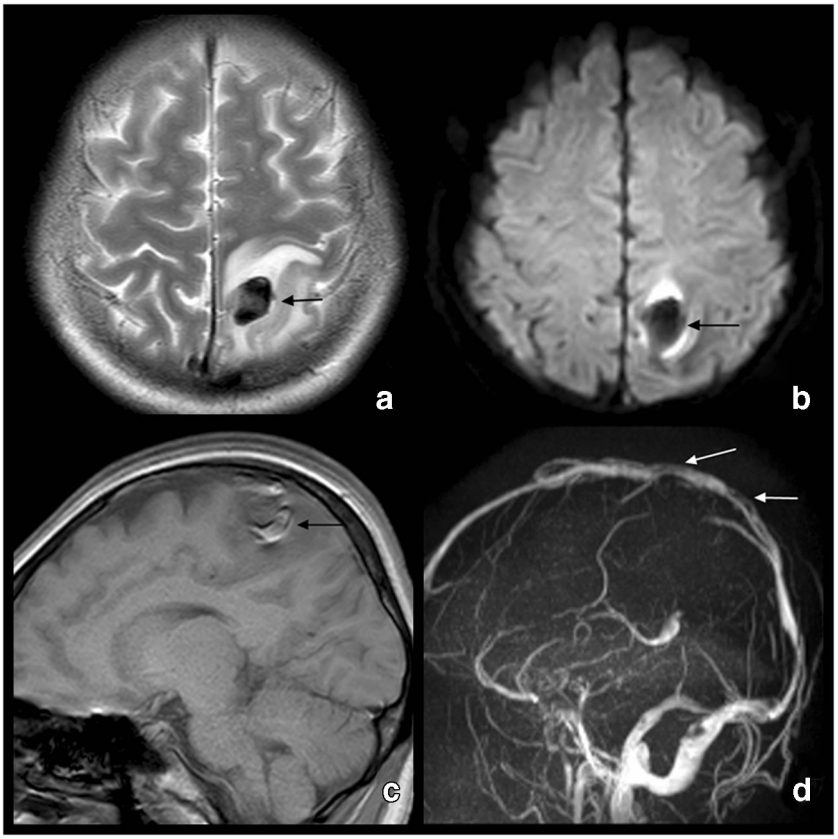

Fig. 3 Cerebral venous thrombosis in a patient with preeclampsia. A 27-year-old patient, 35 weeks pregnant, with seizures during a single month. **a** The arrows show left parietal lobe hypointensities in T2WI; **b** DWI shows hypointensities; **c** sagittal T1WI shows hyperintensities in the same location. **d** MRV shows superior sagittal sinus venous thrombosis

patients with early-onset severe preeclampsia, and the degree of renal insufficiency is more serious than in patients with late-onset.

In our study, 81 (47.1%) patients underwent brain imaging, including 44 patients with early-onset and 37 patients with late-onset severe preeclampsia. Thirty-one of the patients received cranial CT only because of the higher sensitivity to hemorrhagic diseases and the sudden condition of some patients. The differences between abnormal imaging findings in the two patient groups were not significant. Ultimately, 57 patients had positive imaging findings, of which 30 (52.6%) had brain edema, which was the most common finding. Patients with preeclampsia showing cerebral edema have been previously reported [23]. Although the mechanism involved in the development of cerebral edema remains unclear, it is generally believed that the condition is associated with increased vascular permeability as a result of injury to the vascular endothelium, and impaired vascular self-regulation as a result of abnormally elevated blood pressure [24]. The vertebrobasilar artery system, which supplies blood to the posterior brain, lacks sympathetic nerve distribution and is particularly sensitive to changes in blood pressure [25]. When blood pressure increases beyond the range of vascular self-regulation, the contracted arterioles are forced to dilate, resulting in hyperperfusion of the regions supplied by the posterior cerebral artery and brain edema [26]. The CT

Table 2 Imaging findings in patients with neurologic symptoms diagnosed with early and late preeclampsia

Imaging changes	Early preeclampsia ($N = 44$)	Late preeclampsia ($N = 37$)	P value
Cerebral edema (N, %)	18 (40.9)	12 (32.4)	0.4313
Cerebral infarction (N, %)	3 (6.8)	6 (16.2)	0.3242
Cerebral hemorrhage (N, %)	5 (11.4)	1 (2.7)	0.2906
Cerebral venous thrombosis (N, %)	2 (4.5)	3 (8.1)	0.8413
Subarachnoid hemorrhage (N, %)	1 (2.3)	1 (2.7)	0.5522
Cavernous hemangioma	2 (4.5)	3 (8.1)	0.8413
Normal cranial imaging (N, %)	13 (29.5)	11 (29.7)	0.9856
Abnormal cranial imaging (N, %)	31 (70.5)	26 (70.3)	0.9856

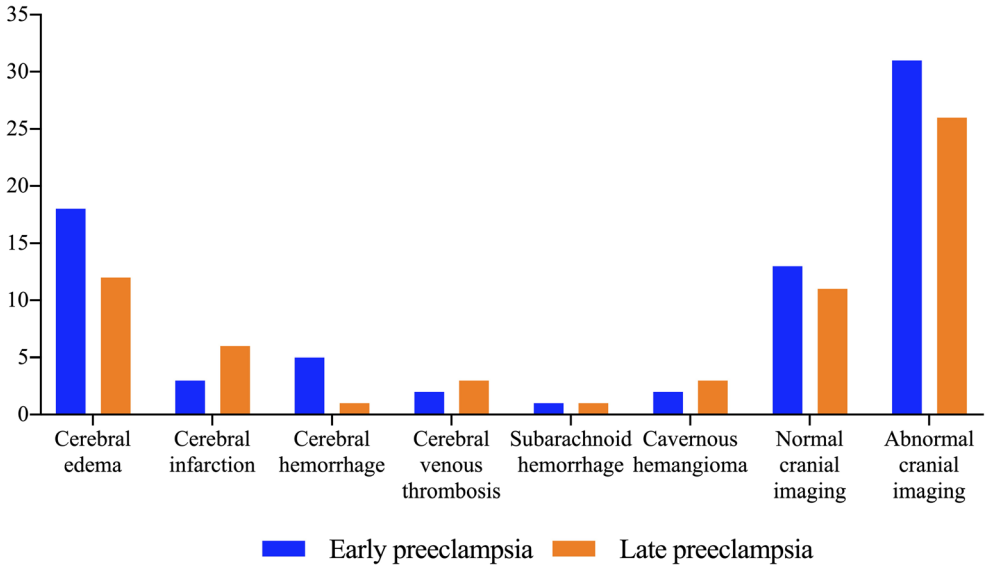

Fig. 4 Comparison of neuroimaging findings between patients with early-onset pre-eclampsia and late-onset preeclampsia

imaging findings consist of scattered or diffuse areas of low density with unclear boundaries in both cerebral hemispheres. The main manifestations on MRI are low signals on T1WI and high signals on T2WI and FLAIR [27]. Moreover, among patients with severe preeclampsia, cerebrovascular problems are common because of marked increases in blood pressure

Table 3 The clinical and laboratory characteristics of patients with neuroimaging positive and negative findings

	All ($n = 81$)	Neuroimaging positive ($n = 57$)	Neuroimaging negative ($n = 24$)	P value
Age, y (mean ± SD)	31.8 ± 4.9	31.4 ± 5.3	32.8 ± 3.7	0.235
Gestation week at diagnosis, w (mean ± SD)	30.9 ± 5.4	29.9 ± 5.6	33.2 ± 4.1	0.014
SBP (mm Hg)	147.8 ± 28.5	147.8 ± 28.5	157.0 ± 22.8	0.164
DBP (mm Hg)	96.5 ± 16.2	95.6 ± 17.0	98.7 ± 14.3	0.104
MBP (mm Hg)	114.5 ± 18.4	113.2 ± 19.1	118.2 ± 16.5	0.078
Clinical symptoms				
Headache (*N*, %)	54 (66.7)	45 (78.9)	9 (37.5)	0.000
Visual disturbances (*N*, %)	33 (40.7)	23 (40.4)	10 (41.7)	0.912
Dizziness (*N*, %)	49 (60.5)	35 (61.4)	14 (58.3)	0.796
Impaired consciousness (*N*, %)	11 (13.6)	11 (19.3)	0	0.050
Hemiplegia (*N*, %)	2 (2.5)	2 (3.5)	0	0.885
Hemidysesthesia (*N*, %)	2 (2.5)	2 (3.5)	0	0.885
Laboratory data				
WBC (10^9/L)	11.6 ± 4.1	12.2 ± 4.2	11.4 ± 3.1	0.433
Neutrophil percentage (%)	77.9 ± 8.9	77.7 ± 9.4	78.6 ± 9.4	0.689
Plt (10^9/L)	157.3 ± 62.7	157.9 ± 68.1	155.9 ± 48.9	0.897
HB (g/L)	112.4 ± 18.1	112.8 ± 18.8	111.5 ± 16.6	0.758
ALT (U/L)	33.3 ± 59.2	32.9 ± 53.9	34.2 ± 71.3	0.932
AST (U/L)	52.9 ± 17.3	49.4 ± 59.2	61.3 ± 20.8	0.777
Uric acid (μmol/L)	406.9 ± 116.6	414.0 ± 118.2	390.3 ± 113.5	0.407
Creatinine (μmol/L)	64.6 ± 20.0	65.9 ± 20.4	61.3 ± 31.3	0.428
BUN (mmol/L)	6.1 ± 2.7	6.5 ± 2.6	5.1 ± 2.6	0.027
Cystatin C (μg/L)	1.4 ± 0.3	1.4 ± 0.4	1.3 ± 0.4	0.141
DD (μg/L)	1636.7 ± 1950.6	1780.7 ± 2228.1	1294.7 ± 986.6	0.309

Figures in parentheses are percentages, unless indicated otherwise

SBP systolic blood pressure, *DBP* diastolic blood pressure, *MBP* mean blood pressure, *WBC* white blood cell, *Plt* platelet count, *HB* hemoglobin, *ALT* alanine transaminase, *AST* aspartate transaminase, *BUN* blood urea nitrogen, *DD* D dimmers

and blood viscosity [28]. Our study showed that the incidence of cerebral infarction, cerebral hemorrhage, and venous sinus thrombosis was higher in our patients with severe preeclampsia than would be seen in normal pregnant patients of the same age, considering the special pathophysiological status of pregnant patients.

Although the differences between the rates of neuroimaging-positive manifestations in the patients with early- and late-onset preeclampsia were not significant, statistical analysis showed that patients with positive neuroimaging results were diagnosed with preeclampsia at lower numbers of gestational weeks ($p = 0.014$), which suggests that patients with early-onset preeclampsia were more likely to have positive imaging results. The headache was more common in patients with positive neuroimaging results than that of patients with negative neuroimaging results. Many studies have been published on the imaging results of pregnant patients with headaches. Secondary causes of headache can be identified in a reported 18 to 27% of pregnant patients with headache who undergo neuroimaging [29, 30]. Our results suggest that secondary factors might account for a larger proportion of headaches in patients with early-onset preeclampsia than in patients with late-onset preeclampsia. Multivariate logistic regression analysis confirmed that headache was independently associated with positive neuroimaging findings. Increased blood urea nitrogen levels generally indicate renal insufficiency, which is one of the manifestations of the progression of systemic diseases in patients and increases the possibility of CNS lesions.

Our study has limitations. First, this was a single-center retrospective study, with a relatively small number of participants. Second, because our center sees more critically ill obstetrical patients than other institutions, the proportion of patients with early-onset preeclampsia is higher than what would be seen in a general study, and the proportion of patients with positive neuroimaging findings is higher than the proportion of similar patients in previous studies [3]. Third, for the screening of patients with CNS signs and symptoms, judging the severity of headache and dizziness is difficult, and we might have only enrolled a large proportion of patients with severe signs and symptoms, while some patients with mild signs and symptoms were not included. This might have accounted for the high frequency of positive neuroimaging results. Fourth, our study did not follow the study participants. The long-term outcomes of patients with preeclampsia who manifested neurological signs and symptoms will be the goal of our next study.

Conclusions

Neurological signs and symptoms are more common in patients with early-onset preeclampsia than in patients with late-onset preeclampsia, which, to the best of our knowledge, has not been reported in previous studies. Although the differences between the rates of neuroimaging-positive manifestations in the patients with early- and late-onset preeclampsia were not significant, patients with preeclampsia and neurological signs and symptoms were diagnosed with preeclampsia at lower gestational weeks. Neuroimaging is essential for the diagnosis of neurological disorders in pregnant women. Our results show that cerebral edema is the most common positive neuroimaging finding. Moreover, headache, although a nonspecific neurological symptom, might be independently associated with positive neuroimaging results.

Compliance with ethical standards

Disclaimer The authors alone are responsible for the content and writing of the paper.

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

Ethical standards This study conformed to the Ethical Guidelines for Medical and Health Research Involving Human Subjects endorsed by the Chinese government.

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