Heliyon 9 (2023) e18470

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Study on the relationship between vertebrobasilar dolichoectasia and posterior cranial fossa space

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ARTICLE INFO

Keywords:
VBD
PCF
Volume
Imaging analysis

ABSTRACT

Objective: To investigate the correlation between vertebrobasilar dolichoectasia (VBD) and posterior cranial fossa (PCF) space.
Methods: The medical records and imaging data of patients with VBD and control group were collected from June 2021 to June 2022 in the Third People's Hospital of Hubei Province. All patients with VBD were graded by head and neck CTA. The grading index was divided into two parts, including vertebral artery bifurcation height and offset degree. Taking the healthy adult subjects of matched age as the control group. The linear volume of posterior cranial fossa was measured by median sagittal CTA images. Middle clivus length, transverse diameter of occipital foramen, supraoccipital length, sagittal diameter of posterior cranial fossa and height diameter of posterior cranial fossa was measured. The volume of the PCF was calculated by 3Dslice software. The relationship between VBD and the volume of PCF was analyzed by SPSS23.0.
Results: The height diameter of posterior cranial fossa, sagittal diameter of posterior cranial fossa, transverse diameter of occipital foramen, clival length, supraoccipital length and space volume of PCF were 34.78 ± 3.67 mm, 85.49 ± 4.15 mm, 30.89 ± 3.94 mm, 44.53 ± 5.36 mm, 45.21 ± 6.45 mm, 171.08 ± 15.81 cm^3 in the case group. The linear volume of PCF and space volume of PCF were significantly lower than those in the control group ($P < 0.05$). Binary logistic regression analysis showed that the independent risk factors of VBD were height diameter of PCF, sagittal diameter of PCF, transverse diameter of occipital foramen, clival length, supraoccipital length and space volume of posterior cranial fossa. According to the classification, the height and diameter of PCF in grade 1 was significantly smaller than that in grade 2 VBD ($P < 0.05$). Under the standard of BA bifurcation degree, there were significant differences between different grades of VBD patients and age ($P < 0.05$).
Conclusion: The smaller volume of PCF may leading the greater possibility of VBD. Under the classification of VBD, the older, the longer the course of disease is, the higher degree of VBD classification is.

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https://doi.org/10.1016/j.heliyon.2023.e18470
Received 25 January 2023; Received in revised form 16 July 2023; Accepted 18 July 2023
Available online 25 July 2023

1. Introduction

Vertebrobasilar dolichoectasia (VBD), a rare cerebrovascular variant disease, is usually an asymptomatic vascular anomaly where the vertebral/basilar artery is elongated, distended, and tortuous, sometimes causing brainstem compression and producing compressive or ischemic/hemorrhagic symptoms [1–4]. Its variation develops slowly and has a high disability rate. VBD mainly shows abnormal extension, expansion and bending of vertebral basilar artery, which can compress brain tissues such as cranial nerve, cerebellum and brain stem, showing changes such as cerebral nerve stimulation and posterior circulation ischemia. Although hemorrhagic cerebrovascular disease caused by VBD is relatively rare, but once hemorrhagic stroke occurs, its symptoms are serious and the prognosis is worse [5–10]. At present, there are few studies on the etiology of VBD. Some results showed that the occurrence and development of VBD are related to vascular inflammation, hemodynamics and other factors leading to vascular remodeling of VBD lesions. Previous report found that age ≥60 years old, smoking, hypertension, hyperlipidemia, drinking history and so on are all risk factors for the onset of VBD. But these factors are also of atherosclerosis and does not have significant specificity [11–13]. So, exploring an specificity risk factor for VBD has a significant clinical meaning.

In the posterior cranial fossa (PCF), there are many important tissues like brain stem, cerebellum. Studies had confirmed that the reduction of the space of PCF is closely related to Chiari I malformation, facial spasm, trigeminal neuralgia, etc [14–16]. These results suggest that the reduction of PCF space, leading to tissue displacement and adjacent tissue compression [17,18]. Because of the displacement of the vertebral basilar artery in VBD, and the low morbidity of VBD in atherosclerosis patients, we speculate that the reduction of the posterior fossa is also an important special cause of VBD.

Since VBD is a variation of posterior cranial fossa vessels, there is little research on whether there is a certain correlation between VBD and its grading degree and the volume of PCF [17–21]. Collectively, considering the vertebrobasilar atherosclerosis is common, but only few VBD patients. And the small PCF space related to many diseases, we speculate that the reduction of the PCF volume is an important cause of VBD. Thus, this paper takes adults with mature skull as the research population, and discusses the linear volume and spatial volume characteristics of the posterior fossa of VBD patients by comparing these normal.

2. Materials and methods

2.1. Patients

Patients with VBD diagnosed in our hospital from June 2021 to June 2022 were selected as subjects. Inclusion criteria: head and neck CTA diagnosed as VBD (basilar artery length >29.5 mm, diameter >4.5 mm or lateral deviation >10 mm; vertebral artery diameter >4.5 mm, or its intracranial segment length >23.5 mm, or any deviation >10 mm) [3,21–23,24,25]. Exclusion criteria: 1) Intracranial space-occupying lesions (tumor, giant aneurysm and so on); 2)Skull bone destruction and partial skull defect; 3) Accompanied by intracranial hemorrhage or other diseases; 4)History of head surgery. Based on the criteria, there were 18 patients

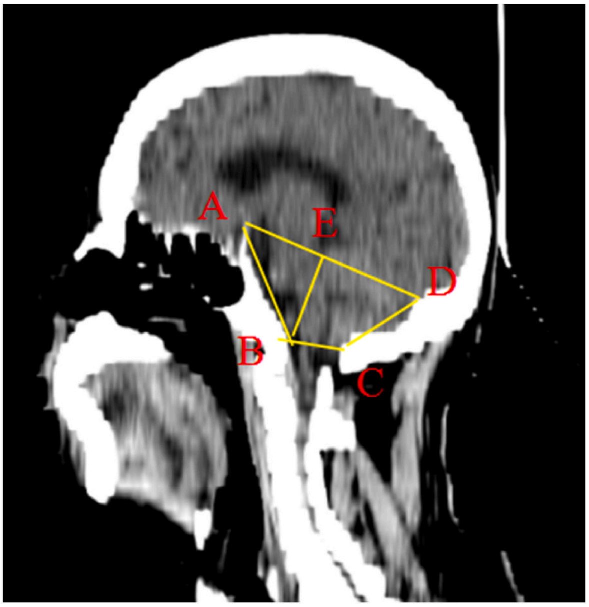

Fig. 1. Measurement of linear parameters between bony markers of posterior cranial fossa on median sagittal CTA (A: dorsal Sellar apex; B: median anterior edge of occipital foramen magnum; C: median posterior edge of occipital foramen magnum; D: intraoccipital Carina; AB: Clivus length; BC: transverse diameter of occipital foramen; CD: supraoccipital length; DA: sagittal diameter of posterior cranial fossa; distance between BE:B point and AD line, that is, height diameter of posterior cranial fossa).

with VBD enrolled in this experiment, including 12 males and 6 females, with an average age of 63 years. The clinical manifestations were dizziness and headache in 10 cases, limb weakness and numbness in 3 cases, hemifacial spasm in 1 case, unstable walking or easy to fall in 3 cases, and diplopia in 1 case. The control group was healthy adult subjects who underwent CTA examination because of dizziness and headache. Among them, 18 healthy adult whose age matched the VBD patients of the experimental group were selected. Meanwhile, the ratio of sex in the control group was the same as that of the experimental group.

2.2. VBD classification

To evaluate the classification of VBD, the head and neck CTA of all patients were scanned with Philips 128-slice spiral CT and slice thickness is 0.9 mm. The contrast agent iohexol was injected through the median elbow vein with a high pressure syringe. According to the bifurcation of the basilar artery, grade 0 was lower or flat the dorsal Sellar level, grade 1 was lower or flat the suprasellar cistern, grade 2 was located between the suprasellar cistern and the floor of the third ventricle, and grade 3 was higher than the third ventricle. According to the grade of offset, the midline of the basilar artery is located at the middle of the dorsum sellae or clival. Grade 1 is between the midline of the slope or dorsal Sellar and the parasellar midline; grade 2, between the medial line and the edge of the slope and dorsal Sellar; grade 3, located at the back of the Sellar, outside the edge of the slope or reaching the cerebellopontine angle cistern [26,27].

2.3. Linear and volume measurement of PCF

The linear volume of the PCF was measured by the distance between the bony markers on the median sagittal face of the PCF on CTA images. Point A was the Sellar point, point B was the median anterior edge of the occipital foramen, point C was the median posterior edge of the occipital foramen, point D was the occipital trochanter. AB was the clival length, BC was the transverse diameter of the occipital foramen, CD was the supraoccipital length, DA was the sagittal diameter of the PCF, and BE was the height of the PCF (the vertical distance from point B to DA) [24]. The details were shown in Fig. 1.

The CTA data of all patients were reconstructed by 3Dslice software, and the skull images were reconstructed, and the space volume of the reconstructed posterior cranial fossa was measured by the software [28]. All space and volume measurements are carried out by an experienced observer. The accuracy of data is determined as 0.01 mm by computer measurement. VBD patients were graded by two experienced observers through their CTA images [28]. The details were shown in Fig. 2.

2.4. Statistical analysis

The data were statistically analyzed by SPSS23.0 software, the data of the case group and the control group were analyzed by

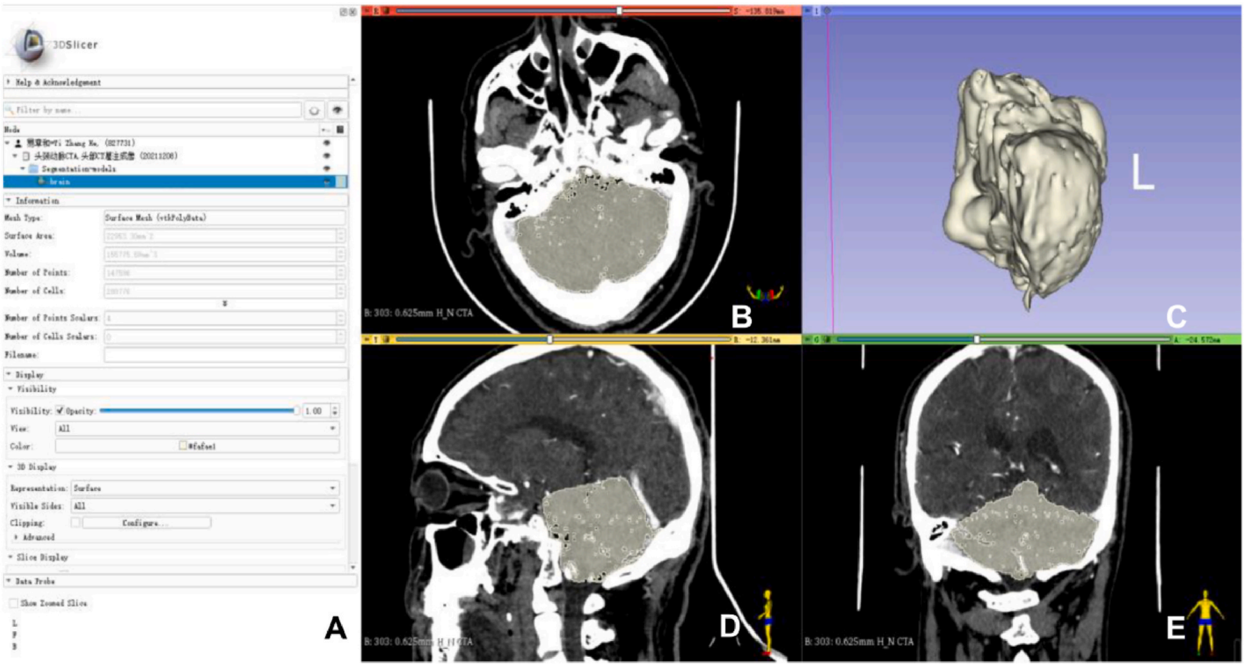

Fig. 2. 3D-Slice software reconstruction of posterior cranial fossa to measure the spatial volume of posterior cranial fossa. A The method of 3Dslice software for reconstruction of the space volume posterior cranial fossa. B, D, E The CTA of posterior cranial fossa in the axial, sagittal, and coronal planes. C The reconstruction 3D volume of posterior cranial fossa.

independent sample *t*-test, and the data were statistically analyzed by binary logistic regression analysis to determine whether the linear volume index and space volume were independent risk factors for VBD. The classification of VBD patients was statistically analyzed by single sample analysis of variance, and the relationship between linear volume and spatial volume of PCF in different grades of VBD patients was compared. The difference was statistically significant ($P < 0.05$).

3. Results

3.1. The PCF volume of VBD patients was significantly reduced

The CTA images of 18 VBD patients were evaluated and graded by two doctors. According to the grade of BA bifurcation, there were 3 cases of grade 1, 12 cases of grade 2, 3 cases of grade 3. Based on the degree of BA offset, there were 3 cases of grade 1, 6 cases of grade 2 and 9 cases of grade 3. Through the statistical analysis of independent sample *t*-test, it was found that the height diameter of PCF (BE), sagittal diameter of PCF (AD) and supraoccipital length (CD) in patients with VBD were lower than those in normal controls, and the difference was statistically significant ($P < 0.05$). Although the transverse diameter of foramen magnum (BC) and clival length (AB) in patients were lower than those in normal controls, but there was no significant difference ($P > 0.05$). The space volume of PCF was 171.08 ± 15.81 cm^3 in VBD patients and 179.76 ± 9.12 cm^3 in control group. The space volume of VBD patients was significantly smaller than that of control group (Table 1). Binary logistic regression analysis showed that the height of PCF, sagittal diameter of PCF, transverse diameter of occipital foramen, clival length, supraoccipital length and spatial volume of PCF were all independent risk factors of VBD. All the indexes were not independent risk factors of VBD (Table 2).

3.2. There was no significant correlation between the grade of VBD and the spatial volume of PCF

The BA bifurcation grade of VBD patients were analyzed by single variance factor analysis. Only in the index of height and diameter of posterior cranial fossa BE. There was a significant difference between grade 1 and grade 2 (grade 1: 29.27 ± 0.01 mm, grade 2: 36.03 ± 3.0 mm, $P < 0.05$). The height of posterior fossa in grade 1 was smaller than that in grade 2, and the difference was statistically significant ($P < 0.05$, Table 3). Other indexes such as sagittal diameter of PCF (AD), transverse diameter of occipital foramen (BC), clival length (AB) and supraoccipital length (CD) were different among different grades, but there was no significant difference ($P > 0.05$). In terms of space volume, the PCF volume of grade 1 patients was 155.78 ± 0.01 cm^3, grade 2 was 172.20 ± 17.00 cm^3, and grade 3 was 181.94 ± 0.01 cm^3. From the average value, the higher the grade of VBD patients, the larger the pPCF volume, but there was no significant difference between ($P > 0.05$, Table 3).

3.3. There was no significant correlation between BA offset grade and PCF

There was no significant difference in linear spatial indexes (PCF height diameter, PCF sagittal diameter, occipital foramen transverse diameter, clival length, supraoccipital length) among different grades of VBD patients in BA offset grade ($P > 0.05$, Table 4). For the space volume, the PCF volume of grade 1 VBD patients was 199.27 ± 0.01 cm^3, grade 2 was 157.16 ± 1.51 cm^3, and grade 3 was 170.97 ± 9.28 cm^3. There was no significant difference between the two groups ($P > 0.05$, Table 4).

3.4. There was a significant correlation between BA offset grade and age

Under the BA bifurcation degree classification, VBD patients were divided into three grades. One-way ANOVA showed that there was a significant correlation between grades and age in VBD patients. Further pairwise comparison showed that there were significant differences between different levels ($P < 0.05$, Tables 5 and 6). Under the BA offset grading standard, there was no significant correlation between age and grades in VBD patients ($P > 0.05$, Tables 5 and 6).

4. Discussion

The study showed that the height of PCF (BE), sagittal diameter of PCF (AD) and supraoccipital length (CD) in VBD patients were significantly lower than those in healthy adult. Compared with the healthy people, the linear volume of the VBD patients was significantly lower. The space volume of VBD patients was also obviously smaller. It can be concluded that the PCF volume (space and

Table 1
Linear volume and spatial volume of posterior cranial fossa in VBD patients and normal control patients (M±SD).

		VBD group (n = 18)	Control group (n = 18)	P
Volume of linearity (Linear distance between osseous marks of posterior fossa)	BE (mm)	34.78 ± 3.67	39.22 ± 6.13	<0.05
	AD (mm)	85.49 ± 4.15	89.50 ± 1.82	<0.05
	BC (mm)	30.89 ± 3.94	31.51 ± 5.20	>0.05
	AB (mm)	44.53 ± 5.36	49.95 ± 4.85	>0.05
	CD (mm)	45.21 ± 6.45	53.12 ± 17.92	<0.05
Volume of space	Posterior fossa volume (cm^3)	171.08 ± 15.81	179.76 ± 9.12	<0.05

Table 2
Independent risk factor analysis of VBD.

	B	S.E.	df	Sig.
BE	9.854	2377.178	1	0.997
AD	7.796	1951.982	1	0.997
BC	15.167	2616.421	1	0.995
AB	−0.12	3452.512	1	1
CD	0.347	375.97	1	0.999
Volume of space	3.433	627.084	1	0.996

Table 3
Linear volume and spatial volume of VBD patients graded according to BA bifurcation level (M±SD) .

		Level 1 (n = 3)	Level 2 (n = 12)	Level 3 (n = 3)
Volume of linearity (Linear distance between osseous marks of posterior fossa)	BE (mm) [a]	29.27 ± 0.01	36.03 ± 3.0	33.65 ± 0.01
	AD (mm)	88.22 ± 0.01	85.60 ± 4.68	82.33 ± 0.01
	BC (mm)	31.22 ± 0.01	30.34 ± 4.77	32.75 ± 0.01
	AB (mm)	38.59 ± 0.01	46.16 ± 5.64	43.96 ± 0.01
	CD (mm)	48.9 ± 0.01	45.44 ± 7.40	40.59 ± 0.01
Volume of space	Posterior fossa volume (cm^3)	155.78 ± 0.01	172.20 ± 17.00	181.94 ± 0.01

[a] It means that there is a significant difference between level 1 and level 2 in the measurement value of each group , $P < 0.05$.

Table 4
Linear volume and spatial volume of VBD patients graded according to BA offset (M±SD) .

		Level 1 (n = 3)	Level 2 (n = 6)	Level 3 (n = 9)
Volume of linearity (Linear distance between osseous marks of posterior fossa)	BE (mm)	34.98 ± 0.01	34.03 ± 5.20	35.22 ± 3.32
	AD (mm)	83.91 ± 0.01	84.58 ± 4.00	86.63 ± 4.87
	BC (mm)	28.24 ± 0.01	29.69 ± 1.68	32.57 ± 4.93
	AB (mm)	46.77 ± 0.01	43.75 ± 5.65	44.31 ± 6.22
	CD (mm)	41.34 ± 0.01	44.22 ± 5.13	47.16 ± 7.83
Volume of space	Posterior fossa volume (cm^3)	199.27 ± 0.01	157.16 ± 1.51	170.97 ± 9.28

Table 5
Correlation analysis between BA bifurcation level and age.

Age in different VBD levels (M±SD)	Level 1 (65 ± 0.01)	Level 2 (59 ± 6.31)	Level 3 (81 ± 0.01)	P
Level 1 (65 ± 0.01)		6 ± 1.82 [a]	−16 ± 0.01 [a]	<0.05
Level 2 (59 ± 6.31)	−6±1.82 [a]		−22 ± 1.8 [a]	
Level 3 (81 ± 0.01)	16 ± 0.01 [a]	22 ± 1.82 [a]		

[a] The comparison between the two groups was $P < 0.05$.

Table 6
Correlation analysis between different grades and age in BA offset grade.

Age in different VBD levels (M±SD)	Level 1 (65 ± 0.01)	Level 2 (61 ± 7.67)	Level 3 (65 ± 12.49)	P
Level 1 (65 ± 0.01)		4 ± 3.13	0.01 ± 4.16	>0.05
Level 2 (61 ± 7.67)	−4±3.13		−4±5.21	
Level 3 (65 ± 12.49)	0.01 ± 4.16	4 ± 5.21		

linear volume) of VBD patients is smaller than that of non-VBD population. The conclusion may be related to the characteristics of VBD disease. One possible explanation may that smaller PCF volume could lead to morphological and hemodynamic changes of vertebrobasilar artery and promote the occurrence of VBD disease.

The anatomical scope of the PCF is above the upper edge of the foramen magnum, below the tentorium cerebellum, the front edge is the slope, and the posterior edge is the occipital bone [19]. There are many methods to measure and calculate the volume of PCF, including the pseudo column volume formula, the scanning pixel calculation method, the linear volume replacement method, etc. The linear volume replacement method can accurately and conveniently reflect volume of the PCF, which is represented by the various PCF bone markers [20]. However, the linear volume cannot accurately show the actual volume of the PCF. The 3D slice software can be used for the measurement and calculation of the spatial volume of PCF [21,22]. Using the software to import and reconstruct CT, MRI and other head scanning datathe, the space volume of PCF can be accurately measured. Therefore, in this study, linear data combined with the space volume of PCF, evaluated by 3D slice software, were used to increase the scientific nature.

The results of binary logistic regression analysis showed that the height diameter of PCF, sagittal diameter of PCF, transverse diameter of occipital foramen, clival length, supraoccipital length and space volume of PCF were not independent risk factors for VBD. This may suggest that VBD is caused by many factors, and there are many risk factors affecting each other. It is impossible to judge whether it will increase the incidence of VBD by one of the linear indexes and space volume of the cranial fossa alone.

Some studies have shown that there are significant differences in posterior circulation blood perfusion among different VBD grades [10]. In order to explore the relationship between VBD grades and PCF volume, VBD patients were graded by BA bifurcation or BA offset. Through the study and analysis of PCF volume with different grades of VBD, the height diameter of PCF in patients with grade 1 was significantly smaller. Although there were not statistically significant differences in linear volume and spatial volume among VBD patients with different grades, indicating that there was no correlation between the degree of grading of VBD patients and the volume of PCF. Only in BA bifurcation classification, the height and diameter of PCF in grade 1 patients was smaller than that in grade 2 patients ($P < 0.05$). The analysis of this phenomenon shows that the BA bifurcation point is higher in patients with grade 2, and the higher diameter of the PCF promotes a higher bifurcation point in BA in patients with grade 3. Although the BA bifurcation point is higher, but the PCF height diameter is smaller than that in grade 2. Of course, these results may also be caused by too small sample size or measurement error and large data deviation is needed.

This experiment explored the difference of PCF volume between VBD patients and normal controls. There was a significant difference between the PCF volume of VBD population and non VBD population. The PCF volume of VBD population was significantly smaller, and the longer the course of disease, the higher the VBD grade. But, the height of PCF, the sagittal diameter of PCF, the transverse diameter of foramen magnum, the length of clivus, the length of supraoccipital, and the volume of PCF are not independent risk factors for VBD. There was no correlation between the VBD patients grades and the volume of PCF. These results may indicate that the small PCF space lead the VBD happening, but not influence the severity of VBD, but this hypothesis need more data to prove.

Related studies showed that age is an independent risk factor for VBD [29]. Under the BA bifurcation degree classification, the older the VBD patients are, the higher the VBD grade is. In other words, the longer the course of VBD, the higher VBD grade. The possible explanation may be that the older age, the more obvious brain tissue atrophy, the greater the activity of BA arteries, the higher bifurcation.

There are still some limitations in this study. Most importantly, with such a rarely diagnosed disorder, the number of patients included in this study is relatively small, and there may be a deviation in its statistical analysis, and resulting the data may not replicate. Perhaps there is a certain relationship between the grading of VBD patients and the volume of PCF, or there is a correlation between the degree of VBD and the course of disease under the standard of BA offset classification. But in this study, the small sample size may be the reason why these two conclusions are negative, so a larger sample are still needed to test. In addition, the relationship between VBD and PCF volume is still unclear, cohort studies are needed to further clarify the relationship between them.

5. Conclusion

To sum up, this study found a significant correlation between VBD and the volume of the PCF. Our results first reveal the relationship between the volume of PCF and the VBD, and indicate that the smaller volume of PCF, the greater possibility of VBD. Under the BA bifurcation degree grading standard, the older the patient and longer the disease course may accompany with the higher VBD grading. These conclusions could help for the diagnosis and prevention of these patients, especially for the population with a small volume of the posterior fossa.

Author contribution statement

Kong Fanji: Performed the experiments; Analyzed and interpreted the data; Wrote the paper, Ye Jianfeng: Performed the experiments; Analyzed and interpreted the data, Lai Li: Analyzed and interpreted the data, Yao Xiaolong: Conceived and designed the experiments; Contributed reagents, materials, analysis tools or data; Wrote the paper, Li Jun: Conceived and designed the experiments; Contributed reagents, materials, analysis tools or data.

Funding

This research received Project of Hubei Provincial Health Commission (WJ2023M115) funding.

Institutional review board statement

The study was conducted in accordance with the Declaration of Helsinki, and approved by the Ethics Committee of Hubei Province.

Informed consent statement

Informed consent was obtained from all subjects involved in the study.

Data availability statement

All data generated or analyzed during this study are included inthis article. There are no separate or additional files.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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