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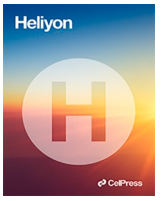

Research article

The effect of the occipital sinus on the torcular Herophili and neighboring structures

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ABSTRACT

Objective: The occipital sinus (OS) has many variations. It is unknown whether OS can change the angioarchitecture of torcular Herophili. Therefore, we performed magnetic resonance venography (MRV) in a cohort of Han Chinese individuals to determine whether OS can change the angioarchitecture of torcular Herophili.

Methods: Participants were divided into a normal OS group and a hyperplastic OS group. Parameters of the OS and torcular Herophili and its neighboring structures were recorded. Statistical analysis was used to determine the effects of OS on torcular Herophili and neighboring structures.

Results: One hundred forty-five healthy participants were enrolled. One hundred patients were in the normal OS group, and 45 were in the hyperplastic OS group. In the normal OS group, the diameters at the transverse sinus (TS) origin were 5.8 ± 2.3 mm on the left side and 7.5 ± 2.2 mm on the right side. In the hyperplastic OS group, the diameters at the TS origin were 6.0 ± 2.1 mm on the left side and 7.0 ± 2.7 mm on the right side. Fenestration was observed in 33% of the torculars in the normal OS group and 6.7% of the torculars in the hyperplastic group. An unpaired *t*-test revealed a significant difference between bilateral TSs in the normal OS group ($P < 0.05$) but no difference in the hyperplastic OS group. The chi-square test revealed a significant difference in torcular Herophili fenestration between the normal and hyperplastic OS groups ($P < 0.05$).

Conclusions: Hyperplastic OS makes bilateral TSs equal in diameter and weakens the predominance of the right TS. A hyperplastic OS reduces the occurrence of torcular Herophili fenestration.

1. Introduction

The torcular Herophili exists at the intersection of the superior sagittal sinus (SSS), straight sinus (SS) and transverse sinus (TS) [1]. The occipital sinus (OS) begins near the torcular Herophili and runs within the attached edge of the cerebellar falx toward the foramen magnum [2]. The OS shows several variations, which may be single or multiple, hypoplastic or hyperplastic [3]. Hyperplastic OSs are uncommon. The hyperplastic OS can act as an important venous draining route to replace the transverse sinus (TS) and sigmoid sinus [4,5]. Hyperplastic OS can affect the torcular Herophili and neighboring structures and is worthy of study.

Dural venous sinuses can be examined by using computed tomography angiography (CTA) and magnetic resonance venography (MRV); furthermore, they can be examined in an invasive manner using digital subtraction angiography (DSA) [6]. MRV is considered the most noninvasive choice for examining the dural sinus [7,8]. To date, there have been an insufficient number of studies using MRV

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to study the OS, torcular Herophili and neighboring structures, especially in a population of healthy Han Chinese individuals. Therefore, we conducted such a study.

2. Materials and methods

A retrospective MRV study was performed on healthy Han Chinese participants at our institution during physical examinations between December 2020 and June 2023. This study was approved by the institutional ethics committee.

2.1. Acquisition parameters of MRV

MRV examination was performed using a 3.0 T MR scanner (Discovery 750, GE Healthcare, WI, USA) with a standard 8-channel

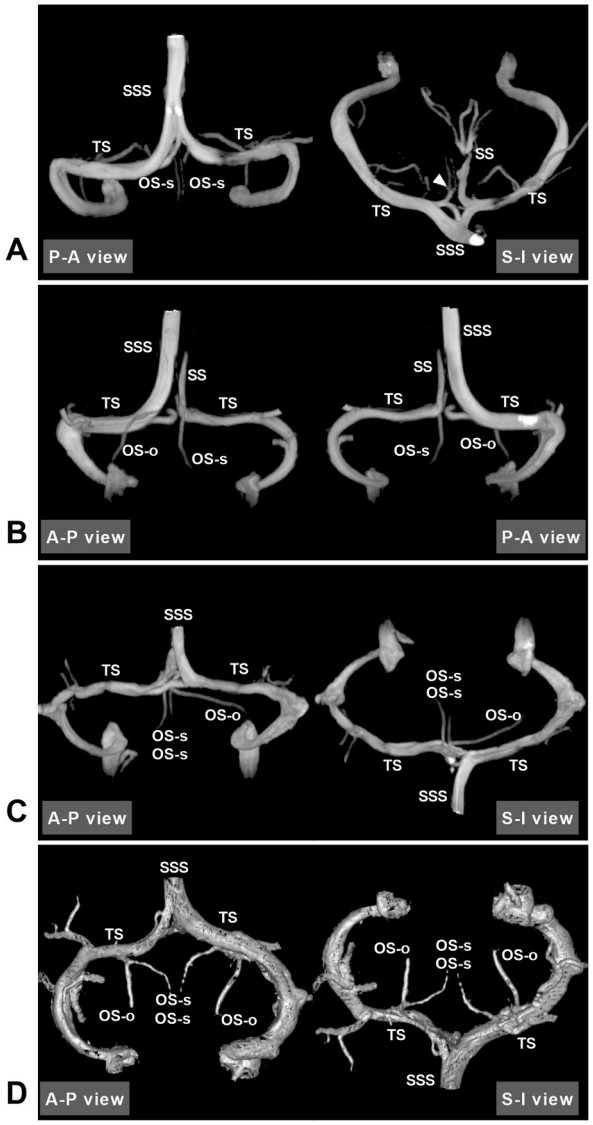

Fig. 1. Normal OS in MRV
A: MRV showing 2 straight OSs (arrowhead) from the fenestration of the torcular. The left panel shows the P-A view, and the right panel shows the S–I view. B: MRV showing 2 OSs: 1 straight OS from the SS and 1 oblique OS from the TS. The left panel shows the A-P view, and the right panel shows the P-A view. C: MRV showing 3 OSs from the torcular, including 2 straight OSs and 1 oblique OS. The left panel shows the A-P view, and the right panel shows the S–I view. D: MRV showing 4 OSs from TS, including 2 straight OSs and 2 oblique OSs. The left panel shows the A-P view, and the right panel shows the S–I view.
Abbreviations: A–P: anterior-posterior, MRV: magnetic resonance venography, OS: occipital sinus, OS-o: oblique OS, OS-s: straight OS, P–A: posterior-anterior, S–I: superior-inferior, SS: straight sinus, SSS: superior sagittal sinus, TS: transverse sinus.

phased-array head coil. The acquisition parameters of three-dimensional-phase contrast MRV were as follows: repetition time = 14.2 ms, echo time = 4.07 ms, field of view = 220 × 220 mm, slice thickness = 1.6 mm, gap = 0.8 mm, matrix size = 512 × 512, flip angle = 8, and frequency direction = anterior/posterior. Raw data were postprocessed on a GE Workstation (version 4.7) (GE Healthcare; Cytiva).

2.2. Inclusion and exclusion criteria

Participants had no intracranial tumors or vascular diseases on recent head computed tomography or MR examinations. The MRV images were clear. MRV clarity was graded into scores of 0, 1 and 2 based on the degree of SS display. On the workstation, a score of 0 indicated no SS display, a score of 1 indicated a blurred SS display, and a score of 2 indicated a clear SS display. Two physicians (Zibo Zhou and Fasheng Zhao) independently rated the clarity of the images, and only images rated by both physicians with a score of 2 were

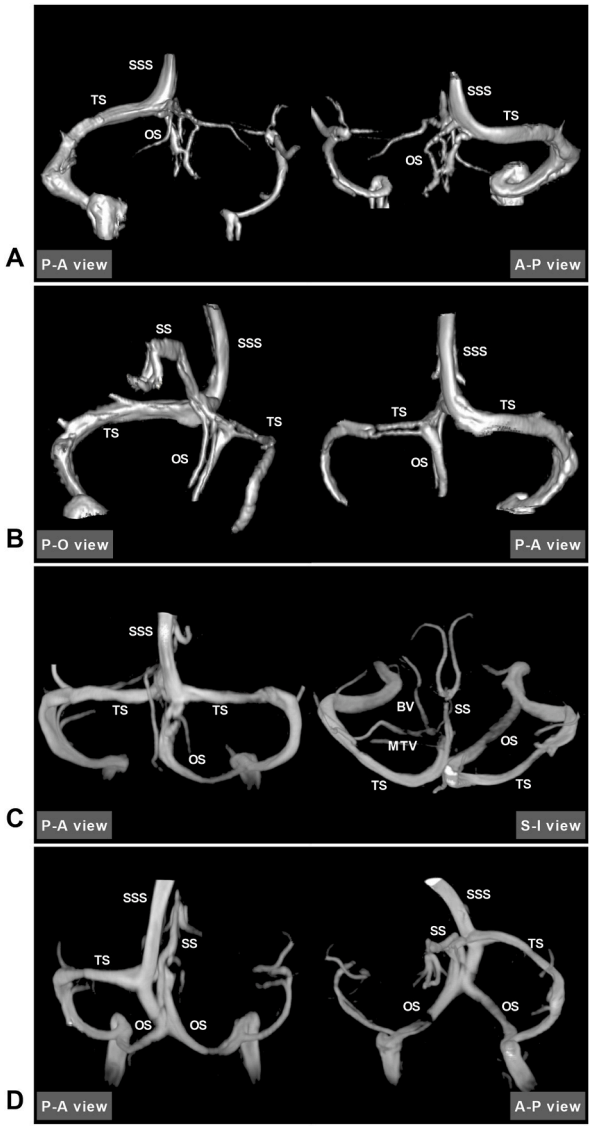

Fig. 2. Hyperplastic OS in MRV

A: MRV showing type I OS. The OS was large and plexiform. The left panel is the P-A view, and the right panel is the A-P view. B: MRV showing type II OS. The OS was large and branchy with one large trunk. The left panel is the P–O view, and the right panel is the P-A view. C: MRV showing type III OS. The OS was ipsilateral and hyperplastic, draining into the sigmoid sinus. The left panel shows the P-A view, and the right panel shows the S–I view. D: MRV showing type IV OS. The OSs were bilateral and hyperplastic, draining into the sigmoid sinus. The left panel shows the P-A view, and the right panel shows the A-P view.

Abbreviations: A–P: anterior-posterior, MRV: magnetic resonance venography, OS: occipital sinus, P–A: posterior-anterior, P–O: posterior-oblique, S–I: superior-inferior, SS: straight sinus, SSS: superior sagittal sinus, TS: transverse sinus.

included in the study.

2.3. Software and tools used for postprocessing

The raw MRV data were postprocessed and reconstructed using a volume rendering procedure on a GE Workstation. A clear three-dimensional MRV image can be obtained by adjusting the window width and widow level. A select tool can be used to rotate the image. The scalpel tool can be used to remove the structures that interfered with the measurement. A straight distance tool was used to measure vessel diameter. Each parameter was measured 3 times by Zibo Zhou and Fasheng Zhao, and the average value was used.

2.4. Grouping

The participants were divided into two groups: the normal OS (OS diameter at origin <3 mm) group and the hyperplastic OS group (OS diameter at origin ≥ 3 mm) (Figs. 1 and 2) [9]. Hyperplastic OSs were divided into four types: type I: plexiform OS, type II: plexiform or branchy OS with one large trunk, type III: ipsilateral hyperplastic OS drained into the sigmoid sinus, and type IV: bilateral hyperplastic OSs drained into the sigmoid sinus (Fig. 2).

2.5. Measured and recorded parameters

The diameters of the TS, SSS, SS and OS were measured (Fig. 3). TSS development was divided into left predominance, right predominance and symmetry. Torculars were divided into seven types and recorded (Fig. 4) [10]. Fenestration of the torcular region was recorded (Fig. 5). The falcine sinus and abnormal basal vein of Rosenthal were recorded (Fig. 6).

2.6. Statistical analysis

Statistical assessments were performed using GraphPad Prism (8.02 (LLC, San Diego, CA, USA)). Continuous variables are expressed as the mean $\pm$ standard deviation. An unpaired *t*-test was used for the comparison of age, the diameters of the TS at origin, and the SSS and SS at termination. A chi-squared test or Fisher's exact test was used to analyze other data. A P value < 0.05 indicated a statistically significant difference.

3. Results

3.1. General information

One hundred forty-five healthy participants who met the inclusion criteria were enrolled, and the flowchart shows the inclusion and exclusion data (Fig. 7). The normal OS group included 100 participants (97.9%, 2080/2125) with an average age of 35.7 $\pm$ 17.5

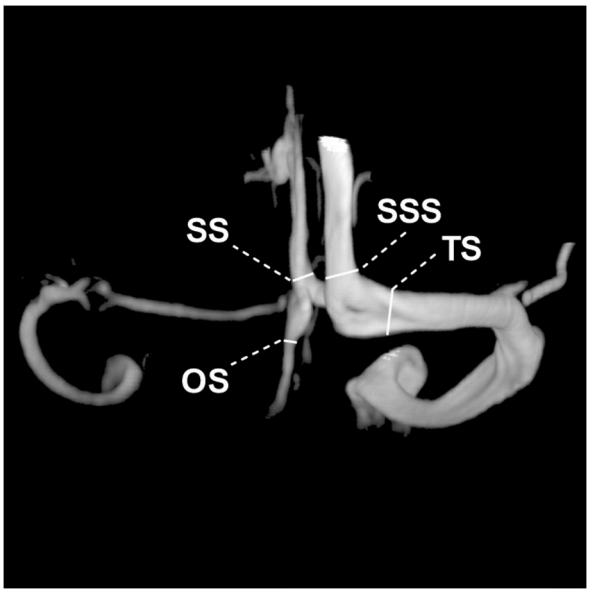

Fig. 3. Diameters of TS, SS, SSS and OS in MRV
The diameters of the TS at origin, SSS at termination, SS at termination and OS at origin were measured.
Abbreviations: MRV: magnetic resonance venography, OS: occipital sinus, SS: straight sinus, SSS: superior sagittal sinus, TS: transverse sinus.

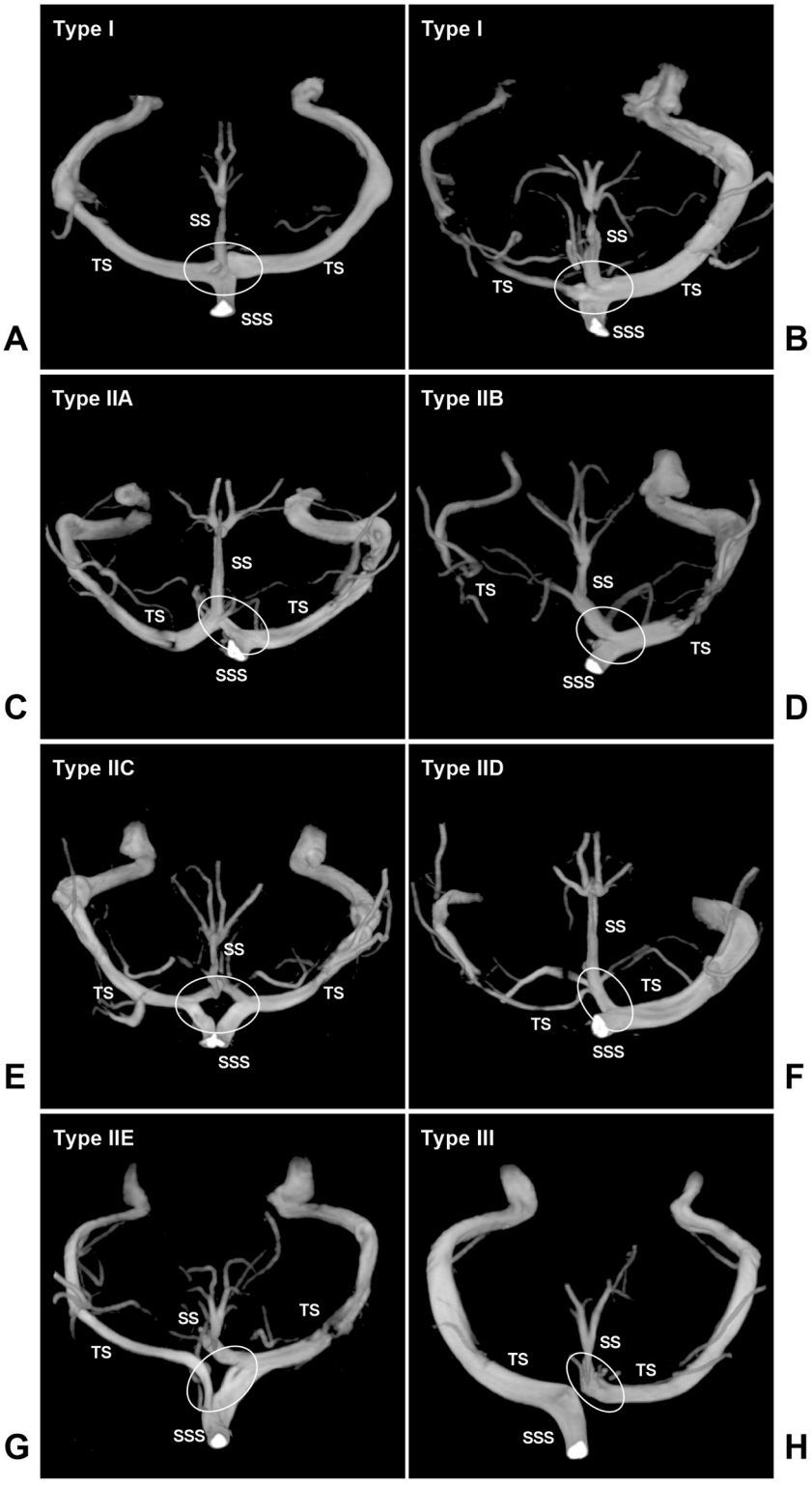

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Fig. 4. Torcular classification in MRV
A-B: Type I, the SSS, SS and TS were connected to form a confluence (circle). C: Type IIA, the SSS emptied into one of the TSs, and the SS emptied into both TS unions. D: Type IIB, the SSS, the SS, and one TS were connected, and the other TS was absent (circle). E: Type IIC, the SSS was split, and the SS was also split (circle). F: Type IID, the SSS emptied into one of the TSs, the SS was split, and one of the branches emptied into this union point (circle). G: Type IIE, the SSS was split, the branches emptied into the TS separately, and there was no union between the two TSs (circle). H: Type III, only two sinuses had a direct union (circle).
Abbreviations: MRV: magnetic resonance venography, SS: straight sinus, SSS: superior sagittal sinus, TS: transverse sinus.

years (range, 10–84 years), and the ratio of male to female participants was 1.1:1 (53/47). The hyperplastic OS group included 45 participants (2.1%, 45/2125) with an average age of 41.3 ± 20.7 years (range, 8–82 years), and the ratio of male to female participants was 0.8:1 (20/25) (Table 1).

3.2. TS development and diameters of the TS, SSS and SS

Normal OS group: TSS development was predominantly right in 59 (59%, 59/100) cases, symmetric in 23 (23%, 23/100) cases, and left in 18 (18%, 18/100) cases. The diameter at the TS origin was 5.8 ± 2.3 mm (2.2–11.6 mm) in 92 left sides and 7.5 ± 2.2 mm (2.1–14.1 mm) in 98 right sides. The diameter at SSS termination was 8.3 ± 1.3 mm (5.2–13.2 mm) in 100 cases. The diameter at SS termination was 4.6 ± 1.1 mm (2.5–7.5 mm) in 100 cases with 102 SSs.

Hyperplastic OS group: TSS development was right predominant in 24 (53.3%, 24/45) cases, symmetric in 9 (20%, 9/45) cases, and left predominant in 12 (26.7%, 12/45) cases. The diameter at the TS origin was 6.0 ± 2.1 mm (2.5–9.9 mm) on 38 left sides and 7.0 ± 2.7 mm (1.0–11.8 mm) on 42 right sides. The diameter at SSS termination was 8.7 ± 1.8 mm (4.3–14.9 mm) in 45 cases. The diameter at SS termination was 4.5 ± 1.7 mm (1.7–9.3 mm) in 45 cases. The detailed data are shown in Table 2. (see Fig. 8)

3.3. Torcular type and fenestration

Normal OS group: The torcular type was type I in 28 (28%, 28/100) cases, type IIA in 19 (19%, 19/100) cases, type IIB in 16 (16%, 16/100) cases, type IIC in 6 (6%, 6/100) cases, type IID in 8 (8%, 8/100) cases, type IIE in 14 (14%, 14/100) cases, and type III in 9 (9%, 9/100) cases. Hyperplastic OS group: The torcular type was type I in 6 (13.3%, 6/45) cases, type IIA in 7 (15.6%, 7/45) cases, type IIB in 12 (26.7%, 12/45) cases, type IIC in 4 (8.9%, 4/45) cases, type IID in 4 (8.9%, 4/45) cases, type IIE in 6 (13.3%, 6/45) cases, and type III in 6 (13.3%, 6/45) cases. The detailed data are shown in Table 3.

There were 33 (33%, 33/100) cases of torcular fenestration in the normal OS group and 3 (6.7%, 3/45) cases in the hyperplastic group (Table 4).

3.4. OS parameters

In the normal OS group with 100 cases, 1 OS, 2 OSs, 3 OSs, 4 OSs, and 5 OSs were observed in 10 (10%, 10/100) cases, 43 (43%, 43/100) cases, 25 (25%, 25/100) cases, 18 (18%, 18/100) cases, and 4 (4%, 4/100) cases, respectively. One hundred cases had 263 OSs in total, and the course of OS was straight in 193 (73.4%, 193/263) OSs and oblique in 70 (26.6%, 70/263) OSs. The diameter at its origin was 1.8 ± 0.5 mm (0.4–2.9 mm) in 263 OSs. The OS origin was torcular, TS, tentorial sinus and SS in 43 (16.3%, 43/263) OSs, 14 (5.3%, 14/263) OSs, 156 (59.3%, 156/263) OSs, and 50 (19%, 50/263) OSs, respectively.

In the hyperplastic OS group with 45 cases, the classification of OS was Type I in 4 (8.9%, 4/45) cases, Type II in 24 (53.3%, 24/45) cases, Type III in 14 (31.1%, 14/45) cases, and Type IV in 3 (6.7%, 3/45) cases. Forty-five cases had 48 predominant OSs (Type IV cases had two OSs); of them, the origin was torcular in 34 (70.8%, 34/48) OSs, tentorial sinus in 12 (25%, 12/48) OSs, and SS in 2 (4.2%, 2/48) OSs.

Except for 4 OSs of type I, the predominant trunk of the other 44 OSs had a diameter at its origin of 4.7 ± 1.8 mm (3.0–11.7 mm). Except for 3 cases with type IV OS and 5 cases with predominant OS at the middle line, in the other 37 cases, TS development at the predominant OS side compared with the opposite side was hypoplastic in 27 (73%, 27/37) cases, symmetric in 9 (24.3%, 9/37) cases, and hyperplastic in 1 (2.7%, 1/37) case.

3.5. Base veins of rosenthal and falcine sinus

Of 100 cases of normal OS, there were 5 (5%, 5/100) abnormal base veins of Rosenthal and 5 (5%, 5/100) falcine sinuses. Of 45 cases of hyperplastic OS, there were 2 (4.4%, 2/45) abnormal base veins of Rosenthal and 5 (11.1%, 5/45) falcine sinuses. The detailed data are shown in Table 5.

3.6. Statistical results

Regarding TS development, an unpaired *t*-test significantly differed between the left and right TSs in the normal OS group ($P < 0.05$) but no difference in the hyperplastic OS group ($P > 0.05$), which indicated that hyperplastic OS increased the diameter of the left TS to make bilateral TSs tend to be equal in diameter. Regarding the relationship of torcular fenestration, the chi-squared test revealed a significant difference between the two groups ($P < 0.05$), which indicated that hyperplastic OS reduced the occurrence of torcular

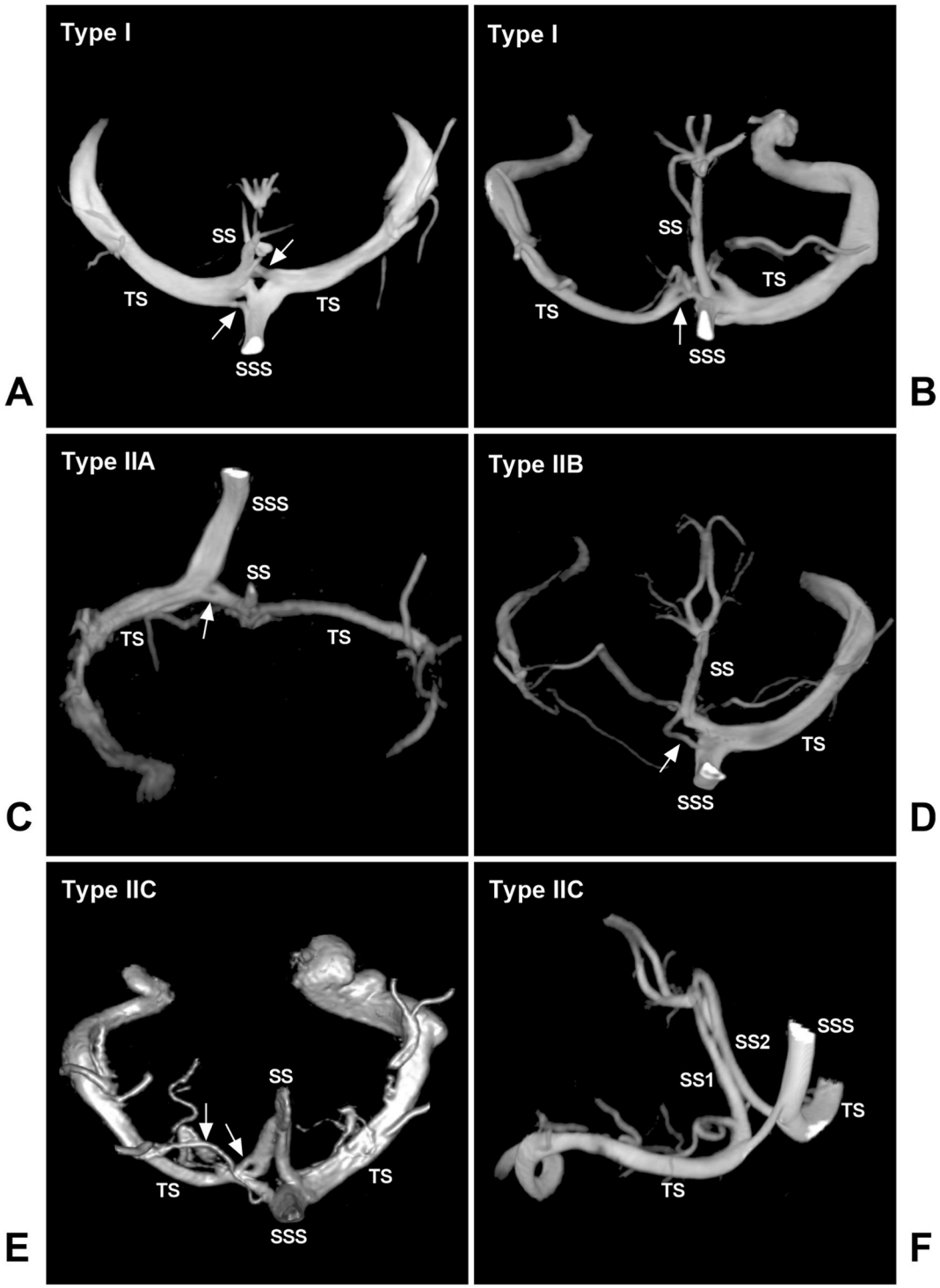

Fig. 5. Fenestration of the torcular region in MRV

A: MRV showing the type I torcular with two fenestrations (arrows). B: MRV showing the Type I torcular with a fenestration at the TS origin (arrow). C: MRV showing the type IIA torcular with fenestration at the junction of the SSS and TS (arrow). D: MRV showing the type IIB torcular with fenestration (arrow). E: MRV showing the type IIC torcular with fenestration (arrow). F: MRV showing the type IIC torcular with duplicate SS (SS1 and SS2) (a narrow and long fenestration). G: MRV showing the type IID torcular with a fenestration at the TS origin (arrow). H: MRV showing the type IID torcular with fenestration (arrow). I: MRV showing the type IIE torcular with fenestration at the SS origin (arrow). J: MRV showing the type IIE torcular with fenestration. K: MRV showing the type III torcular with fenestration (arrows). L: MRV showing the type III torcular with two

fenestrations (arrows).
Abbreviations: MRV: magnetic resonance venography, SS: straight sinus, SSS: superior sagittal sinus, TS: transverse sinus.

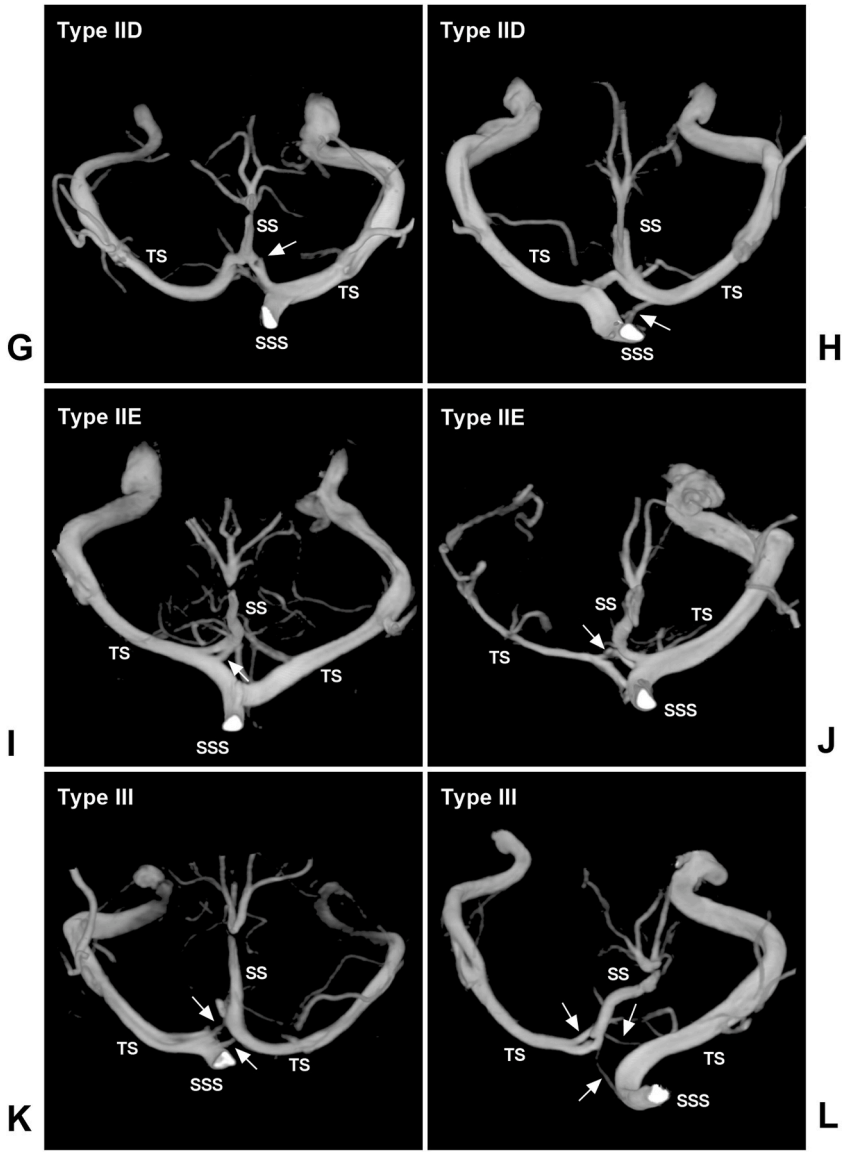

Fig. 5. (*continued*).

fenestration. Regarding the occurrence of abnormal basal veins of Rosenthal and falcine sinuses, the chi-squared test did not show a significant difference between the two groups.

4. Discussion

The OS is the smallest dural venous sinus and is situated near the attachment of the falx cerebelli [11]. In embryology, the OS was shown to develop from the posterior dural plexus and gradually decrease in caliber and number due to diminution and fusion; then, OS with different degrees of development remained [12]. Dural venous sinuses demonstrate maximal growth between 0 and 7 years of age and reach adult size at approximately 10 years of age [13]. Therefore, in our study, children who were 10 years old were enrolled.

The OS was important for open surgery and played an important role in intracranial vascular diseases. OS injury should be avoided during open surgery and occipital screw fixation [6]. A hyperplastic oblique OS could present a hazardous surgical challenge for posterior fossa surgery, and craniotomy or dural opening can result in hazardous bleeding, air embolism, and intraoperative brain bulge due to venous hypertension [14]. Rarely, symptomatic intracranial hypertension can occur due to thrombosis of a persistent OS [15]. The OS can be involved in dural arteriovenous malformation as the draining path [16–18].

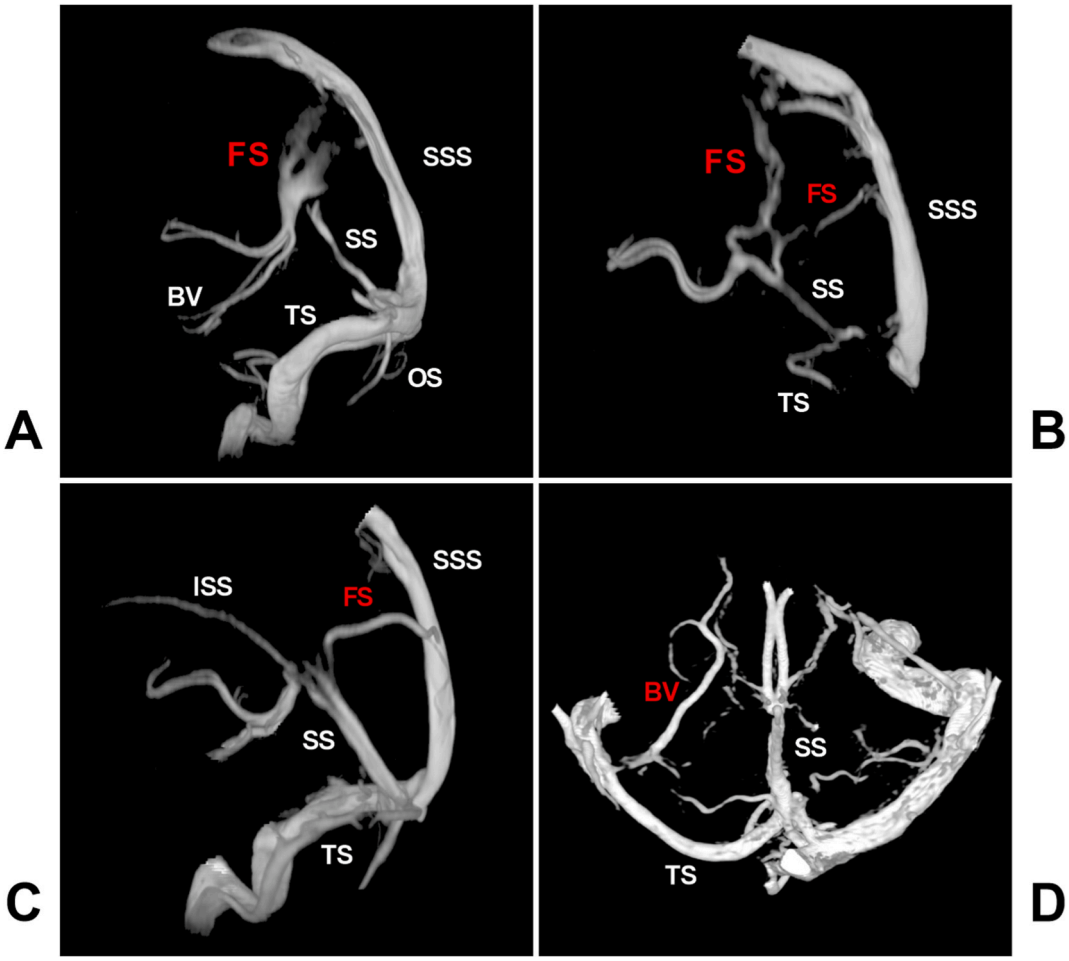

Fig. 6. Falcine sinus, abnormal basal vein and double SS in MRV.
A: MRV showing a wide FS connecting with the SSS. B: MRV showing the two FSs connecting with the SSS. C: MRV showing the FS connecting with a cortical vein. D: MRV showing the basal vein of Rosenthal draining into the lateral tentorial sinus.
Abbreviations: BV: basilar vein, FS: falcine sinus, MRV: magnetic resonance venography, OS: occipital sinus, SS: straight sinus, SSS: superior sagittal sinus, TS: transverse sinus.

When studying OS, cadaver, CTA and MRV studies can be used. Of them, the cadaver was difficult to obtain. In CTA, the bone can disturb dural sinus measurements. In DSA, the three-dimensional reconstruction of the dural sinus was incontinent. MRV is considered the noninvasive choice for evaluating the dural sinus [6–8]. When performing a study of head MR, clarity is important. We used the SS as the reference of MRV clarity because the SS was constant and had an appropriate diameter; when the SS was clearly displayed, the whole MRV image was clear.

In previous reports, the frequency of OS was inconsistent because of the collapse or slow flow of the OS or the discrepancy in image resolution and autopsy technique (Table 6). The outcome of adult cadaveric studies should be closest to the truth, and the frequency of OS can reach up to 93%, which indicates that OSs are very common in the population [19]. In our study, we found that in high-resolution 3.0 T MRV, the OS existed in all clear MRVs, which indicated that everyone had an OS that was not as low as that in previous reports. In addition, some previous reports only considered hyperplastic OS as OS, which was the reason for the low frequency of OS.

Generally, the OS is thin, and the size of the OS has been reported to be < 3 mm at its origin [20]. Uncommonly, it can grow very strongly [12]. Varied configurations of the OS are believed to derive from the various degrees of development and regression during the later fetal stage. Therefore, in our study, we divided the OSs into two types, normal developmental and hyperplastic OSs, by 3 mm diameter of the OS at its origin [9].

The OS may originate from the torcular Herophili, TS, SS, or tentorial sinus and terminate at the vertebral venous plexus, marginal sinus or sigmoid sinus [12]. In MRV, it was easy to distinguish the OS origin. Due to less filling of the distal OS, OS termination was difficult to find directly. However, the OS course provided indirect evidence of the termination. Straight OSs often terminate in the marginal sinus or vertebral venous plexus; however, off-midline oblique OSs terminate in the sigmoid sinus [6].

In our study, for normal developmental OSs, the origins of 263 OSs were torcular in 16.3% of OSs, TS in 5.3% of OSs, tentorial sinus

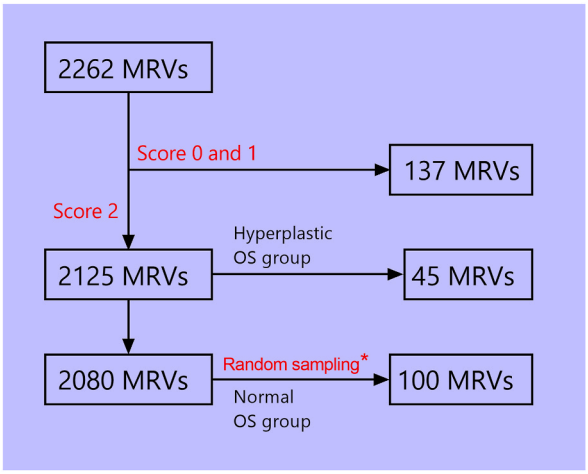

Fig. 7. Flowchart of the inclusion and exclusion data.
Note: Asterisk: simple randomization was performed by using a computer-generated table of random numbers.
Abbreviations: MRV: magnetic resonance venography, OS: occipital sinus.

Table 1
Sex and age.

	Normal OS group (100)	Hyperplastic OS group (45)	P value
Age (years)	35.7 ± 17.5 (10–84)	41.3 ± 20.7 (8–82)	0.0965
Male/female	53/47	20/25	0.3732

Abbreviations: OS: occipital sinus.
In this table, for age, the unpaired *t*-test was used, and for sex, Fisher's exact test was used.

Table 2
TS development and diameters of the TS, SSS and SS.

	Parameter	Normal OS group (100)		Hyperplastic OS group (45)		P value
TS development	L predominance	18/100		12/45		0.4898
	R predominance	59/100		24/45		
	Symmetrical	23/100		9/45		
Diameter	SSS	8.3 ± 1.3 mm (5.2–13.2 mm)/100		8.7 ± 1.8 mm (4.3–14.9 mm)/45		0.1775
	TS L	5.8 ± 2.3 mm (2.2–11.6 mm)/92	P value < 0.0001	6.0 ± 2.1 mm (2.5–9.9 mm)/38	P value = 0.0638	0.7202
	R	7.5 ± 2.2 mm (2.1–14.1 mm)/98		7.0 ± 2.7 mm (1.0–11.8 mm)/42		0.1953
	SS	4.6 ± 1.1 mm (2.5–7.5 mm)/102*		4.5 ± 1.7 mm (1.7–9.3 mm)/45		0.8018

Abbreviations: L: left, OS: occipital sinus, R: right, SS: straight sinus, SSS: superior sagittal sinus, TS: transverse sinus.
In this table, for TS development, the chi-square test was used. For the diameters, the unpaired *t*-test was used.
Note: Double split SS at termination in 2 cases; in total, 102 SSs were included.

in 59.3% of OSs, and SS in 19% of OSs; a straight course was observed in 73.4% of 263 OSs, and an oblique course was observed in 26.6% of OSs. In the Kobayashi et al. study, the OS origin was torcular in 11.4% of cases, TS in 59.4% of cases, dural vein in 26.5% of cases, and SS in 11.4% of cases; the termination was vertebral venous plexus in 44.3% of cases, marginal sinus in 11.4% of cases, and sigmoid sinus in 11.9% of cases [12]. These different incidence rates may result from racial differences or MRI resolution. In addition, the most important issue for the Kobayashi et al. study was that only one OS in one patient was involved in the study. Apparently, it was not unreasonable due to anatomical variation and multiple OS patterns [20].

When the OS is hyperplastic, it can function as the main drainage route of the intracranial veins instead of the TS or sigmoid sinus [2,12,21]. In Shin et al.'s study, a hyperplastic OS was identified in 2.3% (41/1805) of patients, and a hypoplastic or aplastic TS was seen in 75.6% (31/41) of patients with a hyperplastic oblique OS [22]. The results indicated that hyperplastic OSs may affect the structure of torcular Herophili. In our study, there was no difference in the classification of torcular Herophili between the normal and hyperplastic OS groups, which indicated that hyperplastic OS did not change the basic structures of torcular Herophili. However, in our study, the TS lost right predominance, which indicated that the hyperplastic OS indeed affected the popularity of the normal anatomy

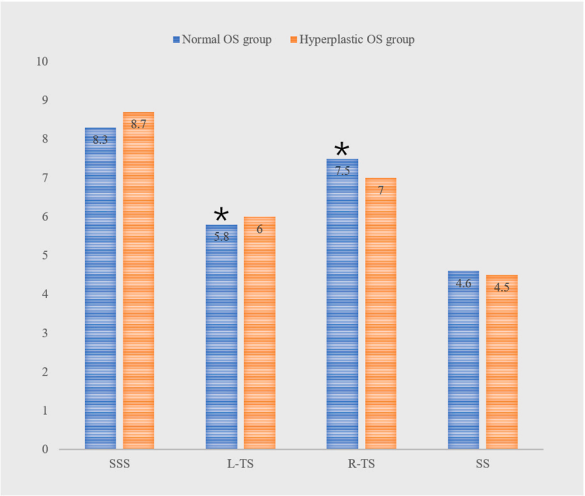

Fig. 8. Column diagram of the main parameters
Diagram showing various sinus diameters, including SSS, TS and SS in different groups; the unit of measure is mm. The asterisks indicate a significant difference between the left and right TSs in the normal OS group.
Abbreviations: L: left, OS: occipital sinus, R: right, SS: straight sinus, SSS: superior sagittal sinus, TS: transverse sinus.

Table 3
Torcular type in the two groups.

Torcular type	Normal OS group	Hyperplastic OS group	P value
I	28	6	0.4391
IIA	19	7	
IIB	16	12	
IIC	6	4	
IID	8	4	
IIE	14	6	
III	9	6	

Abbreviations: OS: occipital sinus.
In this table, the chi-square test was used.

Table 4
Fenestration in the two groups.

	Fenestration	No fenestration	P value
Normal OS group (100)	33	67	0.0004
Hyperplastic OS group (45)	3	42	

Abbreviations: OS: occipital sinus.
In this table, Fisher's exact test was used.

Table 5
Base veins of Rosenthal and falcine sinus in the two groups.

	Normal OS group (100)	Hyperplastic OS group (45)	P value
Base vein of Rosenthal	5/95 (Y/N)	2/43 (Y/N)	0.2855
Falcine sinus	5/95 (Y/N)	5/40 (Y/N)	>0.9999

Abbreviations: OS: occipital sinus, Y/N: yes and no.
In this table, Fisher's exact test was used.

of the torcular Herophili.

Our study investigated the fenestration of torcular Herophili, which has previously never been studied. Fenestration was common in the normal OS group, accounting for 33% of the torcular Herophili. When the OS was hyperplastic, the rate of fenestration of the torcular Herophili was reduced, indicating that the hyperplastic OS affected the development of torcular Herophili. In our study, we encountered the falcine sinus and abnormal basal vein of Rosenthal with uncommon termination. The falcine sinus is a normal

Table 6
Data on OS anatomy in previous reports.

Author/Year	Country	Data source	Main finding
Das et al., /1970 [20]	India	200 cadavers (fresh dura preparations and dried occipital bones)	The frequency of OS was 64.5% of specimens. Different morphological types included median OS (35%), double OSS (22.5%), left OS (4%), and right OS (3%).
Dora et al., /1980 [25]	Turkey	163 retrograde jugular venograms	Of hyperplastic OS, OS drained into the marginal sinus in 38% of cases, OS drained into the superior jugular bulb on one side in 3.9% of cases. There were two OSs. Both drained into the marginal sinus in 6.6% of cases. Both drained into the right jugular bulb in 0.66% of cases.
Kobayashi et al., /2006 [12]	Japan	555 MRVs	Normal and hyperplastic OSs were included, the mean maximum diameter was 3.6 mm. OS origin was torcular in 11.4% of cases, TS in 59.4% of cases, dural vein in 26.5% of cases, and SS in 16% of cases; The termination was vertebral venous plexus in 44.3% of cases, marginal sinus in 11.4% of cases, and sigmoid sinus in 11.9% of cases.
Balak et al., /2010 [9]	Turkey	30 cadavers	The frequency of OS was 93.3%. The OS was normally developed. The length of the OS averaged 26 mm. The inner diameter of the OS at midpoint averaged 3.3 mm.
Cosar et al., //2014 [26]	Turkey	30 cadavers	The frequency of OS was 80%. The OS was normally developed. The diameters averaged 11.7 mm for SSS, 5.3 mm for OS, and 9.7 mm (right) and 9.1 mm (left) for TS.
Lee et al., /2016 [6]	Korea	1720 DSAs	The frequency of OS was 90.2%. They are all normal types. In cases more than 60 years old, one OS was in 55% cases, two OSs in 22.1%, and three OSs in 11.4%. In cases less than 60 years old, one OS was in 57.3% cases, two OSs in 23.4%, and three OSs in 11%.
Shin et al., /2017 [22]	Korea	1805 CTAs	There are 41 hyperplastic and oblique OSs, the rate was 2.3%. Of hyperplastic and oblique OSs, 4.9% had a fenestration.
Larson et al., /2020 [13]	USA	429 MRVs	Of hyperplastic OSs, the rates were 24% in cases of younger than 1 years of age, 25% in cases of 1–5 years of age, 4.8% in cases of 6–10 years of age, 8.6% of 11–15 years of age, and 2.8% in cases of 16–20 years of age, respectively.
Tochigi et al., /2023 [2]	Japan	213 MRVs in Chiari malformation type I	Hyperplastic OS was identified in 7 patients (3.3%). All OSs were found to be of the oblique type.

Abbreviations: CTA: computed tomography angiography, DSA: digital subtraction angiography, MRV: magnetic resonance venography, OS: occipital sinus, SSS: superior sagittal sinus, TS: transverse sinus.

anatomical structure in the fetus that closes after birth and is rarely observed in the adult population [23]. The falcine sinus was defined as a midline venous structure connecting the vein of Galen or the internal sagittal sinus with the superior sagittal sinus, and the rate was 2.1% in Ryu et al.'s report [24]. In our study, the falcine sinus and abnormal basal vein of Rosenthal did not show a tendency in the hyperplastic OS group, indicating that the falcine sinus and abnormal basal vein of Rosenthal may occur accidently and have no association with OS development.

5. Conclusions

Hyperplastic OS did not change the basic structures of torcular Herophili. However, hyperplastic OS makes bilateral TSs equal in diameter and weakens the predominance of the right TS. In addition, hyperplastic OS reduced the occurrence of fenestration in torcular Herophili.

Limitations

The sample size was relatively small, which may lead to an underestimation of the prevalence of hyperplastic OS, thus requiring further external validation. In addition, the study population was limited to Han Chinese individuals, which may limit the generalizability of the results. Further research should investigate these phenomena in diverse populations. In addition, future research should examine the correlation between diameter and handedness.

Ethics statement

This study was approved by the Ethics Committee of the First Hospital of Jilin University (No. 2023-KS-005). All methods were performed in accordance with the relevant guidelines and regulations. The patients/participants provided their written informed consent to participate in this study. Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

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Data will be made available on request.

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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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