Falcine Sinus: Incidence and Imaging Characteristics of Three-Dimensional Contrast-Enhanced Thin-Section Magnetic Resonance Imaging

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Objective: To evaluate the incidence, characteristics, and variations of the falcine sinus with contrast-enhanced three-dimensional (3D) thin-section magnetic resonance (MR) images.

Materials and Methods: A retrospective review identified 1531 patients (745 males and 786 females, 2 months to 85 years) who underwent cranial MR imaging including T1-weighted imaging, T2-weighted imaging, T2-weighted fluid-attenuated inversion recovery, contrast-enhanced 3D thin-section sagittal scans, and MR venography, from June 2014 to January 2016. The incidence, characteristics of the falcine sinus, and coexisted intracranial lesions were confirmed by two neuroradiologists.

Results: Falcine sinuses were identified in 81 (38 males and 43 females) cases (5.3%, 81/1531, 5 months to 76 years of age) with calibers ranging from 2.3 mm to 17.0 mm. Three major forms of falcine sinuses were defined: arch-like (n = 47), stick-like (n = 22), and bifurcated (n = 12). Persistent falcine sinuses were found in 57 cases, among which 3 cases showed complicated cerebral anomalies, and 2 cases showed smaller straight sinuses. Recanalization of falcine sinuses were found in 24 cases, including 17 cases with tumor compression, 6 cases with cerebral venous sinus thrombosis, and one case with hypertrophic meningitis.

Conclusion: Falcine sinus is not as rare as has been reported previously. Most falcine sinuses are not associated with congenital cerebral abnormalities. Diseases that cause increased pressure in the venous sinus may lead to recanalization of falcine sinus. Illustrating the characteristics of falcine sinus may prompt a more comprehensive understanding and diagnosis of associated diseases, and avoid potential surgical damage in the future.

Keywords: Falcine sinus; Magnetic resonance imaging; Thin-section imaging; Contrast-enhanced magnetic resonance imaging

INTRODUCTION

Falcine sinus is a normal venous channel in falx cerebri which connects the vein of Galen and the posterior part of superior sagittal sinus (SSS) during the prenatal period (1-6), and normally closes before or shortly after birth. A falcine sinus that fails to close is defined as persistent falcine sinus, which has been reported in most previous studies as a rare intracranial venous anomaly frequently associated with complicated cerebral abnormalities (6-14).
Systematic investigation with a large sample series was rare (15). The purpose of this study was to evaluate the incidence, anatomic characteristics, and variations of falcine sinus, to assess its clinical significance and obtain a more comprehensive understanding of falcine sinus using a series of cranial MRIs with contrast-enhanced three-dimensional (3D) thin-section sagittal scans.

**MATERIALS AND METHODS**

**Patient Population**

This study was approved by our Institutional Review Board. Contrast-enhanced 3D thin-section sagittal cranial magnetic resonance (MR) images of patients in our hospital from June 2014 to January 2016 were evaluated retrospectively. Patients with a history of neurosurgery or open brain trauma were excluded. A total of 1531 consecutive cases were reviewed, including 745 males and 786 females, aged from 2 months to 85 years.

**Scan Protocol**

All images were obtained with a 3T MR system (MAGNETOM TrioTim, Siemens Healthcare, Erlangen, Germany). MR imaging sequences were axial T1-weighted imaging, T2-weighted imaging, coronal T2-weighted fluid attenuated inversion recovery sequence, 3D thin-section contrast-enhanced sagittal scanning (3D T1-weighted magnetization-prepared rapid gradient echo sequences, repetition time [TR] = 1750 ms, echo time [TE] = 3.26 ms, field of view [FOV] = 226 x 226 mm, matrix = 384 x 384, slice thickness = 0.6 mm, slice gap = 0) and MR venography (gradient-recalled echo sequence, TR = 2.6–2.9 ms, TE = 1.0–1.1 ms, FOV = 640 x 640 mm) after administration of 0.2 mmol/kg gadoterate meglumine (Beilu Pharmaceutical Co., Ltd, Beijing, China).

**Image Analysis**

All the images were observed by two senior neuroradiologists separately, and findings were confirmed based on the consistency between the opinions of the two neuroradiologists. Agreements were achieved after comprehensive discussions about the few cases in which different opinions were held initially by the two radiologists. The presence of the falcine sinus was divided into two categories according to Ryu’s study (15): 1) persistent falcine sinus without venous sinus disease or compression; 2) recanalized falcine sinus with the existence of lesions causing venous sinus obstructions. Analysis of the images included: 1) review for the presence of falcine sinus; 2) definition of the shape and caliber of the falcine sinus; 3) definition of the coexisted diseases that increase the pressure of venous sinuses; 4) situations with congenital cerebral abnormalities; 5) comparison of the falcine sinuses before and after surgeries or other medical treatments; and 6) definition of other cranial lesions and anomalies. Statistical analysis was performed for patients’ demographic information. Kolmogorov-Smirnov test was applied for the test of normality.

**RESULTS**

**Demographic Findings of Falcine Sinus**

For the 1531 consecutive cases, the primary clinical causes for MR imaging were headache (459, 30.0%), confirmed cerebral tumor (245, 16.0%), cranial nerve disorders (196, 12.8%), dizziness (182, 11.9%), systemic diseases (such as lupus erythematosus, screening for metastasis, etc.; 93, 6.1%), asthenia (84, 5.5%),

| Range of Age (Years) | Number of Subjects | Number of Falcine Sinuses | Percentage of Subjects with Falcine Sinus |
|----------------------|--------------------|--------------------------|------------------------------------------|
| 0–10                 | 108                | 7                        | 6.5                                      |
| 11–20                | 133                | 8                        | 6.0                                      |
| 21–30                | 127                | 9                        | 7.1                                      |
| 31–40                | 265                | 18                       | 7.0                                      |
| 41–50                | 340                | 15                       | 4.4                                      |
| 51–60                | 323                | 14                       | 4.3                                      |
| 61–70                | 173                | 8                        | 4.6                                      |
| 71–80                | 53                 | 2                        | 3.8                                      |
| 81–90                | 9                  | 0                        | 0                                        |
| Total                | 1531               | 81                       | 5.3                                      |
intracranial hypertension (74, 4.8%), vomiting (66, 4.3%),
epilepsy (34, 2.2%), tinnitus (32, 2.1%), dystaxia (25,
1.6%), and others (insomnia, disorder of consciousness,
etc.; 41, 2.7%).

Eighty-one out of 1531 patients were identified with
falcine sinuses (5.3%), including 38 males and 43 females,
with ages ranging from 5 months to 76 years, which were
normally distributed (Table 1). The incidence of falcine
sinus in the two sexes was similar, with 5.1% (38/745) in
males, and 5.5% (43/786) in females. Our results indicated
that the incidence of falcine sinus was evenly distributed
indifferent sexes and ages.

Clinical Findings of Falcine Sinus

A total of 81 patients showed falcine sinuses. Fifty-seven
cases (3.7%, 57/1531) exhibited persistent falcine sinuses
(Fig. 1). 1) Three cases had complicated abnormalities,
including one case with the absence of the splenium of
corpus callosum, multiple cysts, and parietal abnormalities
of schizencephaly associated with gray matter heterotopia
next to the central line; one case with ectasia of superior
SSS, falcine sinus and the vein of Galen, associated with
Chiari’s I malformation; and one case with partial absence
of the corpus callosum and arteriovenous malformation
of the pericallosal vessels (Fig. 2). A rudimentary straight
sinus was observed in the above 3 cases. 2) Two cases only
showed rudimentary of the straight sinus without other
malformations. 3) The other 52 cases did not show any
congenital cerebral anomalies.

Twenty-four cases (1.6%, 24/1531) exhibited
recanalization of falcine sinus (Fig. 1). 1) Seventeen
cases showed tumors compressing the adjacent veins
(Fig. 3), including 11 cases of meningioma, 2 cases of
hemangiopericytoma, and 1 case each of the following:
ganglioglioma, pilocytic astrocytoma, medulloblastoma, and
giant tumor in the posterior cranial fossa. In 10 subjects,
of the tumors located next to the falx cerebri, 4 were in the posterior fossa/cerebellum, and 3 were in the middle fossa. Except for 2 subjects lost to follow-up, the other 15 cases underwent surgical operations; follow-up MR examinations showed no changes of the recanalized falcine sinuses (Fig. 4). 2) Six cases presented with multiple venous sinus thrombosis mainly involving SSS and transverse sinus. One case showed falcine sinus thrombosis (Fig. 5). MRI follow-up examinations of the 6 cases after treatment demonstrated no change of the falcine sinuses. 3) One case showed hypertrophic meningitis (Fig. 6).

**Imaging Characteristics and Classification of Falcine Sinus**

Contrast-enhanced 3D thin-section sagittal MR scans clearly showed direction, anatomical structures and connection with the surrounding structures of the falcine sinus. In our study, the falcine sinus presented as blood vessels connecting the vein of Galen, or as the anterior part of the straight sinus with SSS, with calibers between 2.3 mm to 17 mm (7.3 ± 4.1 mm). They were categorized into 3 groups based on their imaging characteristics: 1) 47 cases of arch-like falcine sinus that exhibited as an curved vessel protruding towards the front (Fig. 3), three of these cases were located near the occipital pole connecting the anterior part of the straight sinus and the posterior part of SSS; 2) 22 cases of stick-like falcine sinuses that exhibited as a straight vessel and in most cases with a large caliber (Fig. 4); 3) 12 cases of bifurcated or branch-like falcine sinuses.
that connected the vein of Galen or the anterior part of the straight sinus and the posterior part of SSS with two or more branches of vessels (Fig. 2). One case of branch-like falcine sinus was initially mistaken as the drainage vessel of an arteriovenous malformation (Fig. 2).

**DISCUSSION**

**Embryology of Falcine Sinus**

Falcine sinus is a vascular channel between the two layers of falx cerebri that is present during the fetal period and usually closes before birth (1-3). Continued presence or recanalization of the falcine sinus after birth is considered to be a variation or anomaly. During early embryonic development, the primitive falx cerebri contains the sagittal plexus, a mesh of anastomotic venous loops. As the dorsal dominant venous channel of the sagittal plexus eventually develops into the anterior aspect of SSS, the ventral aspect of the sagittal plexus becomes the inferior sagittal sinus and the straight sinus, and the smaller channels between them disappear (1, 2, 4). With the development of the occipital lobe, the SSS and straight sinus start extending towards the occipital pole, recruiting more caudal venous loops of the sagittal plexus and forming a complete SSS and straight sinus. Falcine sinus is formed by one of the caudal anastomotic loops of the sagittal plexus (1, 2), and disappears after complete development of the SSS and straight sinus. The development of the falcine sinus is closely associated with that of the posterior aspect of the SSS and the straight sinus (5, 6).

Some studies suggested that persistent or recanalized falcine sinus might result from an enlargement of certain venous channels caused by an obstruction of the venous sinuses (1, 2). Although located between posterior part of the SSS and the vein of Galen or the anterior part of straight sinus, the falcine sinusues observed in our study varied in morphology, including arch-like, stick-like, bifurcation and branches. This indicated that instead of developing from one specific venous channel of the sagittal plexus, the falcine sinus may form by a random opening of certain venous channels or the combination of a number of small channels. These findings might inspire further thought when studying the embryology of falcine sinus. Moreover, our study found that the falcine sinuses near the occipital pole appeared to be small and the upper end seemed to be close to torcular herophili, indicating that these falcine sinuses might be the traces of incomplete degradation of sagittal venous plexus during the convergence of the SSS and straight sinus towards the occipital pole.

**The Incidence of Falcine Sinus**

Previous studies (6-13) reported that falcine sinus was a rare congenital variation. Ryu (15) challenged this conclusion when they analyzed the CT cerebral venous angiography of 586 cases and found that the incidence was 2.1%. Our study of 1531 cases showed that the incidence of falcine sinus and persistent falcine sinus was 5.3% and 3.7%, respectively, which was in consistent with the conclusion that falcine sinus might not be a rare variation. The incidence of falcine sinus in our study was higher than that in Ryu’s study, which might resulted from the difference of imaging method. We analyzed the thin section enhanced MRI images, while Ryu’s study was based on CT venous angiography. MRI image has better soft tissue resolution than CT, and the minimum caliber of the falcine sinus observed in our study was 2.3 mm.

Kaplan et al. (16) conducted a cadaveric study and found 16 (21%) out of 78 specimens had venous channels connecting the superior and inferior sagittal sinus, which also indicated the possibility of high incidence of falcine sinus. In addition, Kaplan’s study suggested that such venous channels were seen in all ages, which is in accordance with the even distribution of falcine sinus in subjects with different ages in our study.

**Clinical Significance of Falcine Sinus**

**Diagnosis as a Congenital Variation**

Anomalies of straight sinus and SSS are commonly combined with falcine sinus as a result of their embryonic correlations during the fetal period (4, 6, 7, 15). These anomalies generally include aplasia, or absence of the venous sinus, and their incidence is low. Most cases are asymptomatic. Only 2 cases were found in our study.

Most cases of falcine sinus combined with cerebral abnormalities were presented in case reports. The reported abnormalities were as followed: dysplastic tentorium cerebelli and malposition of the SSS (15), dysplastic tentorium and enlarged parietal foramina (6, 8), dilation of the vein of Galen, and mid-brain arteriovenous malformation (9, 10), pericallosal arteriovenous malformation associated with absence of the posterior parts of the corpus callosum (9), total absence of the corpus callosum (9), Apert’s syndrome (acrocephalosyndactyly) (9),...
osteogenesis imperfecta, and Chiari’s II malformation (9),
parietal skull defect, and meningoencephalocele (11). Only
3 out of 57 cases in our study presented with complicated
malformations; persistent falcine sinus with complicated
malformation suggest that almost all malformations
appeared close to the midline region. We speculate
that persistent falcine sinus may be part of the midline
dysplasia.

It has long been thought that persistent falcine sinus was
usually associated with complicated abnormalities, probably
because these patients (mostly children) sought medical
treatment due to symptoms related to cranio cerebral
anomalies. Asymptomatic patients were less likely to
undertake systematic craniocerebral examinations; therefore
large scale screenings were rare. Our study and Ryu’s (15)
large-scale investigation both indicated that persistent
falcine sinus is not frequently associated with complicated
craniocerebral abnormalities. It should be noted however,
that both study subjects were Asians, and thus may not
represent all ethnic groups.

Based on our observations, several diagnostic
considerations should be noted: 1) falcine sinus should not
be considered as venous malformation when there is no
associated abnormality; 2) as a special venous sinus, falcine
sinus might also have venous thrombosis. When venous
thrombosis forms in falcine sinus, contrast-enhanced MRI
scan can fail to identify its position without the filling of
contrast medium, which leads to missed diagnosis; 3) when
adjacent vascular malformations exist, falcine sinuss should
not be mistaken as massive drainage vessels, and should be
determined by its relationship to SSS and straight sinus.

Function as a Venous Drainage Channel
As a special venous channel, falcine sinus can be
recanalized in two main circumstances: straight sinus
embolism during the fetal period, and chronic obstruction
of the straight sinus due to the pressure of adjacent tumors
in adults (1). Recanalization of the falcine sinus caused
by venous sinus thrombosis has also been described in
previous studies (1, 15).

There were 24 cases of recanalized falcine sinus in the
current study. We speculate that increased pressure inside
venous sinuses might lead to recanalization of potential
venous channels such as falcine sinus. In our study, the
external causes of increased inner pressure were tumor
compressions (especially those near the meninges and
closely associated with the venous sinus) and compressions
on venous sinuses by the thickened meninges due to
hypertrophic meningitis. The internal cause was venous
sinus thrombosis, likely due to the recanalized falcine
sinus increasing venous drainage and building collateral
circulation (13). Follow-up contrast-enhanced MR images
of 21 cases (15 cases of tumor after surgery and 6 cases
of venous sinus thrombosis after thrombolytic therapy)
 demonstrated that all the recanalized falcine sinuses
remained open with no significant changes in shapes or
locations after treatment. We believe that the recanalized
falcine sinuses may no longer close probably due to the
unidirectional regulation of blood circulation of falcine
sinus.

Consideration during Surgery
During endovascular or surgical obliteration of the
straight sinus, the falcine sinus may assist venous drainage
and is vital to cerebral blood drainage and intracranial
pressure regulation (17). For surgeries involving falx
cerebri, the existence of the falcine sinus may increase the
risk of iatrogenic hemorrhage. Attention should be paid to
the falcine sinus in the preoperative examination, especially
with tumors such as meningioma that tend to compress
venous sinuses (13).

This study had limitations. The subjects of this study
were all Asians and may not represent all ethnic groups. In
addition, cerebral digital subtraction angiography was not
used to confirm the MR venography results in this study.

In conclusion, our investigation of a large number of
retrospective cases using cranial magnetic resonance
imaging with contrast-enhanced 3D thin-section sagittal
scans suggested that falcine sinus is not a rare variation
as reported before, and is not frequently associated with
complex craniocerebral abnormalities. Clearly illustrating
the characteristics of falcine sinus with the use of MR
imaging may prompt more comprehensive understanding
and diagnosis of the associated diseases and avoid potential
surgical damage.

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