Utility Of Non-Contrast MR Venography In Detection Of Normal Anatomy, Anatomical Variations And Potential Diagnostic Pitfalls In Diagnosis Of Cerebral Venous Sinus Thrombosis.

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INTRODUCTION

The venous system of the brain is a complicated system that is distinct from the venous systems of the other sections of the body because it does not adhere to the standard pattern of the cerebral artery system.[1]Both the cerebral veins and the dural sinuses lack valves and do not have tunica muscularis, which would otherwise enable the veins to enlarge and stay dilated in response to even prolonged blockage. Because veins do not have valves, blood can flow in both ways via them, which can lead to an infection spreading throughout the brain from the scalp and mastoid air cells. In order to diagnose normal variant cerebral venous sinus, it is vital to have knowledge of the normal variant in the anatomy of the cerebral dural venous sinus visible on magnetic resonance (MR) venography.[1]The precise functions of the major dural venous sinuses vary from one another depending on their position inside the cranium and the related structures of the cranium that are traversed by the sinuses. [2]

Due to the various pitfalls in image interpretation that are caused by Sinus Hypoplasia and Atresia, the most common of which is the left transverse sinus hypoplasia, as well as the variations of normal venous anatomy that can mimic sinus thrombosis and lead to an over diagnosis or an incorrect diagnosis, it is possible that sinus thrombosis will be misdiagnosed. Flow Gaps on TOF MR Venography most frequently manifest themselves in the non-dominant transverse sinus, in conjunction with arachnoid granulations. Arachnoid granulations are structures that often project into the dural sinus lumen or lateral lacunae. When the newborn is placed in the supine position, the compression may be more pronounced compared to when the head is examined in the decubitus position.[3]The non-contrast bright-blood MRV approach known as two-dimensional time-of-flight, or 2D TOF, depend on inflow blood to produce a vascular signal.[4]

The TOF offers a good structural evaluation for major vein blood flow estimation and vascular stenosis diagnosis. This is possible because of the TOF's high resolution. The pulse sequences that make up TOF are either gradient-echo or spoiled gradient-echo, and they are carried out in sequential order. Each phase-encoding step is carried out in a single slice, resulting in additional suppression of stationary tissue before switching to the next slice. This is done before moving on to the next slice. The blood flowing into the slice is not at saturation, so it stands out brilliantly against the darkened backdrop. The MRV is an extremely helpful modality for determining the normal anatomical variants and examining the anatomy of the cerebral veins. Patients with renal insufficiency or those who are allergic to contrast can utilise this procedure without risk because it does not include contrast.[4]

The non-contrast enhancement method of magnetic resonance angiography known as phase contrast (PC) is based on the phase shift that is acquired by spins as they move along a magnetic field gradient. The flow of arterial and venous blood, as well as the flow of cerebrospinal fluid, may all be visualised and quantified with the help of PC.[4]

The paramagnetic property of intravenous gadolinium is used to shorten T1 and provide positive intravascular contrast enhancement in the more modern venographic technique known as contrast-enhanced MR venography with elliptic centric ordering. When compared with contrast-enhanced TOF MR venography, contrast-enhanced MR venography provides superior imaging of small vessels.[4]

Hence, through this study, we aimed to assess the normal anatomy and anatomical variations of cerebral venous sinuses using non-contrast MRV.

METHODS AND MATERIALS

This is a prospective cross-sectional study performed in the Department of Radiology,Dr. D. Y. Patil Medical College and Hospital and Research Centre, Pimpri, Pune. The study was performed between September 2020 to August 2022, and the sample size included 500 patients. Institutional Ethical Committee (IEC) clearance was obtained before the start of the study. IESC/PGS/2020/175

Method of diagnosis: Siemens Magnetom Vida Magnetic Resonance Imaging (3 Tesla)and Siemens Magnetom Avanto (1.5 Tesla)

The study included all the patients undergoing MRI brain with MR venography as a part of routine headache protocol and MR Venography in all other cases where clinically indicated and advised by the clinician. Those patients with Intracranial aneurysm clips or Intra-orbital metal fragments or Any non-MRI compatible orthopaedic implants that are electrically, magnetically, or mechanically activated, such as cardiac pacemakers, biostimulators, neurostimulators, cochlear implants, and hearing aids, contraindications to contrast agent, history of claustrophobia, history of Cerebral venous sinus thrombosis, excluded clinically and radiologically and those cases that are post-operative and post radiotherapy.

MRI SCAN TECHNIQUE

Patient positioning: - Place the patient in a supine position with the head aimed at the magnet (head first supine).The patient is asked to lie supine & not to move during the study.
Head positioned in head coil and immobilized with cushions. Laser beam localizer centered over glabella.

Planes used: - Axial, sagittal and Coronal

Sequences Used: -

1. 2-dimensional (2D) time-of-flight (TOF)-
   TR:28-35 TE:5-8
   Matrix- 256 x 92
   FOV- 260
   Slice thickness- 3.5mm
   Plane-coronal

2. 3D phase-contrast(PC)-
   TR:70.6 ms TE:7.6 ms
   Slice thickness – 1 mm
   Plane – sagittal
   Matrix- 205x256
   FOV- 250

3. Contrast study –

- With contrast Gadobenatedimeglumine 5 ml

- Angio_fl3d_cor_pre_veno
- angio_fl3d_cor_post_veno

Subtraction based study- angio_fl3d_cor_pre_veno- angio_fl3d_cor_post_veno is done.
Maximum intensity projection studies.

STATISTICAL ANALYSIS

MS Excel was used to enter the data. SPSS v22 was used for the analysis. Categorical variables were represented by frequencies and proportions. Continuous variables were tested for normality with the Kolmogorov Smirnov statistic, and were found to be non-normally distributed. The relationship between sex, comorbidities, and continuous variables was analysed using the Mann-Whitney test, to investigate the relationship between continuous variables, Spearman correlation was applied, statistically significant p value of 0.05 is considered.

RESULTS

This study included 500 patients in whom we aimed to study the normal variation in the dural venous sinuses. This study showed that majority of the study participants were between the ages of 31-40 years.

In the current study, we found that the majority of the study participants were female (n=281).

SEX	FREQUENCY	PERCENTAGE
Male	**219**	**43.8%**
Female	**281**	**56.2%**

Table 1:- sex distribution of study participants

Normal venous anatomy of the dural venous sinuses is seldom seen in routine scanning. Most often, we do find variations, which we should be aware of, so as to not misdiagnose them to be an abnormality. In our study, we found that more than half the patients had a variation in the normal venous anatomy.

NORMAL VENOUS ANATOMY	FREQUENCY	PERCENTAGE
YES	**218**	**43.6%**
NO	**282**	**56.4%**

Table 2:- presence of normal venous anatomy of study participants

Left transverse sinus is also known to have variations such as hypoplasia, atresia, and focal filling defects due to arachnoid granulations. In our study hypoplastic left transverse was the commonest variant.

Right transverse sinus is also known to have variations such as hypoplasia, atresia, and focal filling defects due to arachnoid granulations. Hypoplasia was the commonest variation.

Left sigmoid sinus are known to have variations such as hypoplasia, atresia, and focal filling defects due to arachnoid granulations. In our study we found that majority of the study participants had hypoplastic left sigmoid sinus as a variant.

Right sigmoid sinus are also known to have variations such as hypoplasia, atresia, and focal filling defects due to arachnoid granulations. In our study we found that majority of the study participants had hypoplastic right sigmoid sinus as a variant. However, most of them had a normal right sigmoid sinus.

Variation transverse sinus	Total	Percentage
Transverse sinus		
Left sided hypoplastic	174	34.8%
Left sided atretic	27	5.4%
Right sided hypoplastic	31	6.2%
Right sided atretic	7	1.1%

Table 3:- Distribution of transverse sinus and its variations in the study participants

Variation of sigmoid sinus	Total	Percentage
Sigmoid sinus		
Left sided hypoplastic	144	28.8%
Left sided atretic	15	3%
Right sided hypoplastic	22	4.4%
Right sided atretic	1	0.2%

Table 4:- Distribution of sigmoid sinus and its variations in the study participants

Variations in the superior sagittal sinus are very rare, and most often missed on scanning. In our study, hypoplastic and atretic anterior 1/3rd of SSS are the common variations.

SUPERIOR SAGITTAL SINUS	FREQUENCY	PERCENTAGE
Normal	**482**	**96.4%**
Hypoplastic anterior 1/3rd of SSS	**5**	**1%**
Atretic anterior 1/3rd of SSS	**5**	**1%**
Hypoplastic anterior 2/3rd of SSS	**2**	**0.4%**
Bifurcation of the anterior 1/3rd of SSS	**1**	**0.2%**
Focal filling defects due to arachnoid granulations	**5**	**1%**
Grand Total	**500**	**100%**

Table 5:- Distribution of superior sagittal sinus and its variations in the study participants

sinus, when present, can be unilateral or bilateral. In our study, the most common was a right occipital sinus. The most common amongst the transverse sinus was left sided. When we analysed the variations in anatomy of the dural venous sinuses, we observe that hypoplasia and aplasia of left sided transverse sinus was more predominant. In our study, we find that the right transverse and sigmoid sinus shows dominance in our study participants.

OCCIPITAL SINUS	FREQUENCY	PERCENTAGE
Right occipital sinus	**6**	**1.2%**
Bilateral occipital sinus	**2**	**0.4%**
Left occipital sinus	**1**	**0.2%**
Grand Total	**9**	**1.9%**

Table 6:- distribution of occipital sinus and its variations in the study participants

The symmetry of transverse sinus and sigmoid sinus is an important variation noted on MRI. In our study, we find that the right transverse and sigmoid sinus shows dominance in our study participants.

SINUS DOMINANCE	LEFT	RIGHT	SYMMETRY
Transverse sinus	**38**	**200**	**262**
Sigmoid sinus	**23**	**159**	**318**

Table 7:-Dominance analysis in the study participants

Torcular herophilii in our study was most commonly found in female, and is majority of the times type II.

TORCULAR HEROPHILII	MALE	FEMALE

TYPE I	**70**	**103**
TYPE II	**95**	**128**
TYPE III	**54**	**47**

Table 8 :- Distribution of Trocular herophilii in the study participants

Arachnoid granulation can cause flow disturbances in normal dural venous sinuses. In our study, we found it most commonly seen in SSS.

Flow gaps in the dural venous sinus was seen in 24 out of 500 study participants. In our study, flow gaps were most commonly seen in transverse sinus (right /left or both) in their medial thirds. Flow gaps in straight sinus and superior sagittal sinus are at least observed. Other sinus which flow gap is seen were Straight sinus and Right transverse sinus. Flow gaps are observed in transverse sinus in 22/24 cases. Flow gap in superior sagittal sinus and straight sinus is observed in other 2 cases.

DISCUSSION

The purpose of the study was to assess normal variations and normal structural variations in cerebral venous sinuses in the Indian population. There were 500 research participants in all.

AGE OF STUDY PARTICIPANTS

According to studies conducted around the world, the majority of the study's participants were aged between 31 and 40, which was concurrent with the findings of our study. The patients in Gourav goyal et al study's[4] had a mean age of 37.98 +/- 13.83 years. The mean age of the study population in Elizabeth Kouzmitcheva et al's paediatric CVST research[5], which looked at 51 cases, was 5.9 years [0-17 years].

SEX DISTRIBUTION OF STUDY PARTICIPANTS

In the current study, there were more female participants than male participants. In a short research of 30 individuals using MR angiography, Tulupov AA et al.[6] discovered that men had posterior circulation arteries with bigger diameters than women did (basilar and posterior cerebral arteries)[6]. Although there was no discernible difference between males and females in the anterior circulation arteries. 91 men and 166 women made up the 257 cases. Flow reduction through the right sigmoid sinus occurred more commonly in the female group than in the male group. In the male group, the frequency of flow reduction through the left sigmoid sinus increases with age. Right sigmoid sinus flow decrease is more common in older females. In our study, symmetrical transverse and sigmoid sinuses were more prevalent in females than in males. Compared to women, men showed more hypoplastic left transverse sinuses. The significance of gender differences in the cerebral venous sinus morphology is unknown [6,7]. Males have a higher variation rate than females, it was discovered. In a study on paediatric CVST by Elizabeth Kouzmitcheva et al. [5], they looked at 51 patients, 28 of which were men (55%) and were evaluated. Since they may be seen in childhood and do not change during successive imaging exams, it is thought that these variations are the result of a congenital disorder unrelated to ageing or other degenerative processes. [8,9]

NORMAL VENOUS ANATOMY

In our study, we found that majority of the study participants had normal venous anatomy. In our study, we focussed on those normal anatomic variations. Such a study has seldom been performed in the past, making the findings of our study valuable. In a study by Gourav Goyal[4], we found that the findings of our study was similar to theirs.

DISTRIBUTION OF DURAL VENOUS SINUSES IN MRI

TRANSVERSE SINUS

The current investigation found hypoplastic left and right transverse sinus in 34.8% and 6.2%, respectively, and symmetrical transverse sinus in 41.6%. This discrepancy in our study can be related to the population's ethnic diversity. Alper et al. [10] described anomalies of the transverse sinus. In 31% of cases, symmetrical transverse sinuses were reported. 39% of instances had a hypoplastic left transverse sinus, whereas 20% had an aplastic one. In 6% and 4%, respectively, the right transverse sinus was hypoplastic and aplastic. Surendra Babu et al. [11] conducted a study on 100 individuals, finding that 10% of the patients had symmetrical transverse sinuses, 35% had hypoplastic left transverse sinuses, 13% had hypoplastic right transverse sinuses, and 1% had aplastic left transverse sinuses. In a research by Ayanzen et al. [3], MR venography revealed that 31% of the normal, asymptomatic group had a left hypoplastic sinus.

SIGMOID SINUS

The most frequent anatomical alteration was a hypoplastic left sigmoid sinus, which affected more women than men. Other sigmoid and transverse sinus anatomical variances between the sexes did not significantly differ, Gourav Goyal et al study's [4] found that the most frequent anatomical alteration in sigmoid sinus was a hypoplastic left sigmoid sinus. In our study hypoplastic left and right sigmoid sinus in 28% and 4.4%, respectively, and symmetrical sigmoid sinus in 67.6%.

SUPERIOR SAGITTAL SINUS

The most frequent SSS variant, as noted by Kaplan et al. and Hacker et al [12] is the hypoplasia of the rostral portion of the SSS, which is second only to preferential draining of the SSS to one of the transverse sinuses. In 7 of 382 (1.8%) anatomic specimens in one series and in 12 of 201 (6%) specimens in a second anatomic series, Kaplan and Browder [12] discovered hypoplastic rostral SSS. According to Kaplan et al. and Hacker et al.[12] when the rostral section of the SSS is completely hypoplastic, two substantial parasagittal superior frontal cortical veins that connect the beginning of the SSS close to the coronal suture serve as the missing component's replacement.

Ruiz et al. examined the hypoplasia of the rostral region of the SSS using CT angiography in a series of 100 individuals. In 3% of individuals, complete hypoplastic rostral SSS was noted. In Surendra Babu et al study's [11], 9% of cases of this anomaly were reported. In our study, 0.1% of the SSS had atresia, and 0.1% had hypoplasia. In our study, the SSS was normal in 96.4% cases. Common anatomical variations observed are hypoplastic anterior 1/3rd of SSS, atretic anterior 1/3rd of SSS and focal filling defects in the SSS (1% of cases in each). Other less common variations which were seen are hypoplastic anterior 2/3rd of SSS and Bifurcation of anterior 1/3rd of SSS (0.4% and 0.2% each respectively).

OCCIPITAL SINUS

The smallest of the dural venous sinuses, the occipital sinus is normal located in the midline. It communicates with the torcula haemophili, superiorly it is attached to margin of falx cerebella and communicates with marginal sinus and vertebral venous plexus inferiorly at the foramen magnum. Rarely, it deviates from the midline to join sigmoid sinus and is called oblique occipital sinus. Rarely isolated thrombosis of occipital sinus can occur. It can become source of clival epidural hematoma and can cause difficulty during occipital craniotomy. In various investigations, occipital sinuses were reported in 4.5% to 35.5% of cases. Persistent occipital sinuses were found in 13% of patients younger than 25 months old in research by Rollins N et al.[7], but in just 2% of children older than 5 years. This study lends credence to the idea that the occipital sinus will involute once the infant is standing upright and the majority of the venous flow has passed through the big dural sinuses. In our investigation, 1.9% of the patients had an occipital sinus found which was aligned with the previous studies. Right occipital sinus was commonly observed (1.2%) than bilateral occipital sinus (0.4 %) and the left occipital sinus(0.2 %).

SINUS DOMINANCE AND LATERALITY

In our study, we find that the right transverse sinus and sigmoid sinus were dominant (40 % and 31 %) in both cases of hypoplasia and aplasia of the contralateral side. It is also found that symmetry of the above-mentioned sinuses were visualized in 52 % of the population for transverse sinus and 63 % of the population for sigmoid sinus.

Fifty-six of 192 (29.2%) PC-MRVs without transverse sinus thrombosis showed non-visualization of the same in a study by Chang et al. [9] In 24.0% of these instances, the left TS was NV and was therefore thought to be smaller than the right TS. In 5.7% of cases, the right TS was NV, and in 3.1% of cases, it was thought to be smaller than the left TS. According to research using various imaging modalities, the left and right TSs are hypoplastic in 39%–60% and 6%–14% of individuals, respectively. These findings are consistent with such observations.[13].

According to several anatomic studies [13,14], right TS dominance is the most typical pattern (45-75%). Left dominance (14–29%) and symmetry (19–41%) were less common. Another anatomic investigation by Park et al. [14] revealed that 58.1% of people had symmetry and that 35.5% had right dominance.

Right dominance was reported in 56% of radiological studies utilising angiography, symmetry in 26%, and left dominance in 18%, according to Modic et al. [15] and Shima et al.[16] conducted an analysis of 253 angiographies and discovered right dominance in 51.3%, 33.5% are symmetric, and 9.5% are left-dominated. In retrospective angiographic research with 189 patients, Durgun et al.[17] found that 18.5% of patients had left dominance drainage, 41.3% had right dominance drainage, and 37.6% had equal drainage. 18% have dominance. Shima et al.'s [16] analysis of 253 angiographies revealed right dominance in 51.3% of cases, symmetry in 33.5%, and left dominance in 9.5%. A retrospective angiographic research by Durgun et al. [17] with 189 patients revealed that 18.5% of patients had left dominance drainage, 41.3% had right dominance drainage, and 37.6% had equal drainage.

According to a study by Friedmann et al. [18] based on CT scans, men have a larger venous system than women do, and right-sided venous dominance is most prevalent (70–80% of the time). According to them [18] investigation's using magnetic resonance venography, the right TS's mean calibre (6.5 mm +/-1.84 vs. 5.1 mm +/-1.72) was noticeably larger than the contralateral sinus. In 61% and 17% of the instances, respectively, right and left dominance was noted.

ARACHNOID GRANULATIONS

Arachnoid granulations are projections of the arachnoid villi into the dural sinuses. These allow the flow of CSF from the sub-arachnoid space into the venous system. In our study, arachnoid granulations were found in 13 cases (2.6 %). These were commonly observed in SSS (1%) followed by left transverse sinus, right sigmoid sinus (each 0.4 %). Less are observed in right transverse sinus, straight sinus, left sigmoid sinus (each 0.2 %).

Arachnoid granulations (AG) vary greatly in terms of their size, shape, number, and placement. Sometimes, AG can imitate a malignant osteolytic lesion by growing partially up the inner table of the skull as foveolae granulations, expanding into the diploic region, and eventually involving the outer table. According to a theory, some AG grow older-related sizes and numbers in response to rising CSF volume and pressure. Near the entry points of the superficial veins, the intersection of the middle and lateral thirds of the transverse sinuses (92%) is where AG are most frequently observed [13,14].

Uncertainty surrounds AG's role in medicine. Although giant AG are commonly discovered accidentally in the transverse and posterior superior sagittal sinus, they are occasionally linked to symptoms of increased intracranial pressure caused by venous hypertension related to partial sinus obstruction [(11).]

FLOW GAPS

Flow gaps, are mostly caused by in-plane flow, complex blood flow patterns, and artefacts from sluggish intravascular blood flow. Different methodologies or inclusion criteria used in different research may account for variations in the occurrence of hypoplastic or atrectic rostral third of SSS. In research by Surendra Babu et al[11],flow gaps in SSS and partly split SSS were reported in 24% and 12%, respectively . In 5% of instances in a study by Sharma et al [19], small segment flow gaps in SSS were noted. In our investigation, 24 patients had flow gaps that were observed.

In our study, 24 patients (4.8%) had flow gaps. Similar results were obtained by Goyal G et al [4], who showed 5% flow gaps. However, Arazen et al. [3] showed a substantially greater rate of flow gaps in the transverse sinus, up to 31%, in their investigation.

The study's shortcomings include its single-centre design, the absence of contrast-enhanced MRV, and the lack of long-term follow-up information needed to assess the importance of MRV's anatomical differences. Case selection bias and more variance may be missed in a single centre study. In the current investigation, reporting by a single radiologist could lead to biased interpretation. Venous flow in the plane of image capture may result in saturation, nulling of the venous signal at TOF MR Venography, and incorrect diagnosis due to improper picture interpretation. Due to a reduction in the effects of turbulent flow, contrast-enhanced MR Venography provides a better visual of the dural sinuses. The current investigation may have misinterpreted the flow gaps or other anatomical differences of the dural sinuses due to the lack of contrast-enhanced MRV. To get over these restrictions, prospective studies using contrast-enhanced MRV should be performed to confirm flow gaps , atretic dural venous sinus or autopsy series should be developed in the future.

TORCULAR HEROPHILII

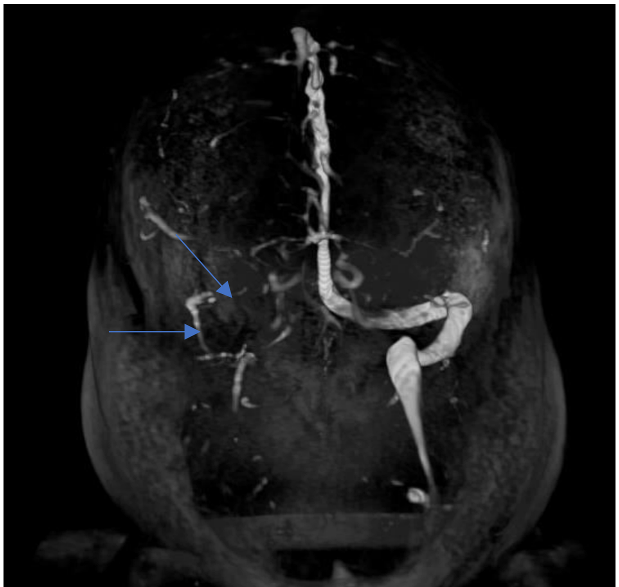
Torcular herophilii in our study was most commonly found in female and is majority of the times type II. In a study done by Erkan Gokce et al[13], partial confluence (type II) was most frequently seen, 1/3 of dural venous sinuses were true confluence torcular type that we have accepted as non-variation type and 2/3 of the sinuses were partial or non-confluence types that included different variations. There were statistically significant differences between the co-presence of the partial confluence type torcular and the occipital sinus (p = 0.040). Park et al. [14]studied 31 adult cadavers and divided torcular Herophili into classes based on inflow, communication and outflow zones. In torcular outflow, the most common type was free communication (83.8 %), while none of the specimens had non-communication type.

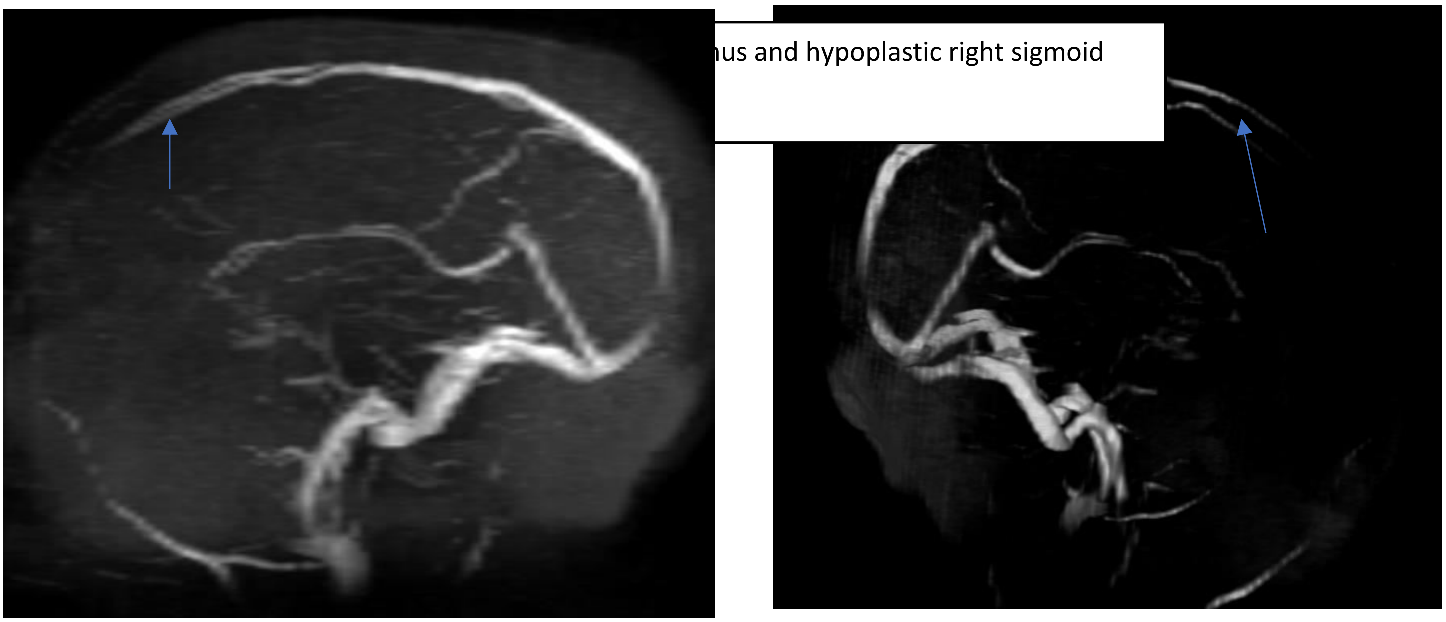
Conclusion

It's crucial to understand the various cerebral dural venous sinus anatomical configurations. In the absence of this, venous sinus thrombosis may be misdiagnosed as a flow gap,hypoplasia,or aplasia of the transverse sinus. In the current investigation, the most frequent anatomical variant is a hypoplastic left transverse sinus. Females are more likely than males to have a hypoplastic left transverse sinus. Other dural venous sinus structural variations are not significantly different between the sexes.

CASE IMAGES

Figure :- Hypoplastic left transverse and sigmoid sinus





nus and hypoplastic right sigmoid

Figure:- Atretic anterior one third of SSS

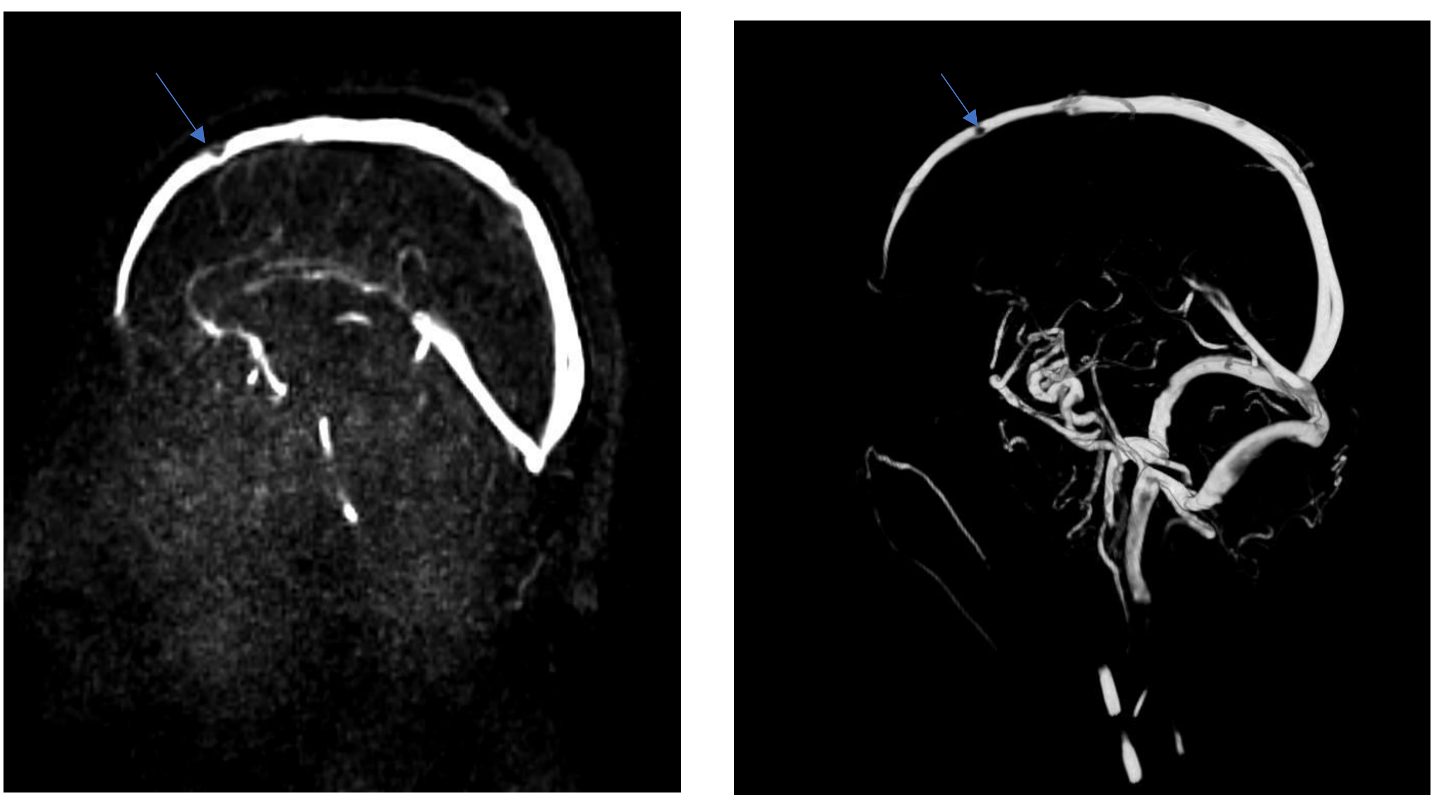
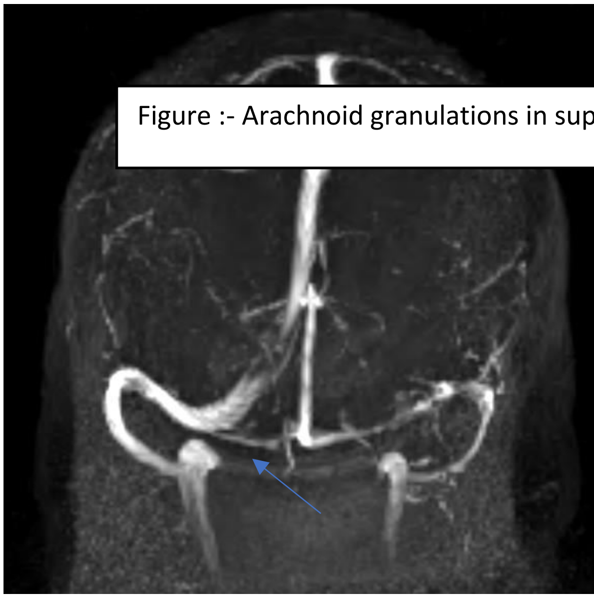


Figure :- Arachnoid granulations in superior sagittal sinus



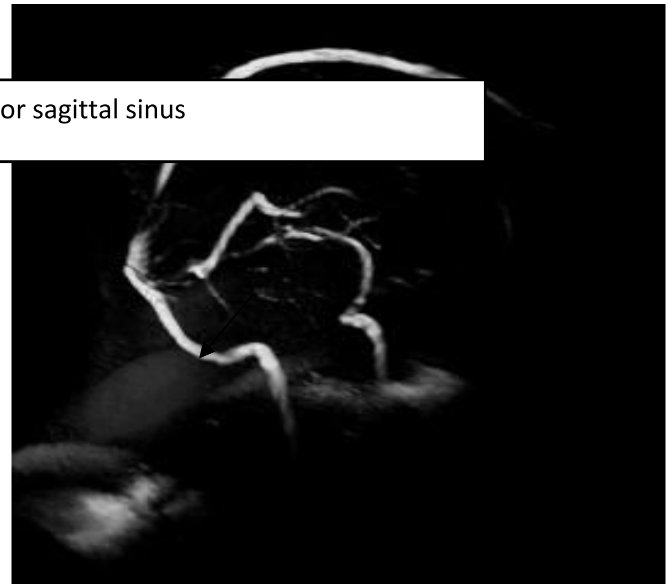


Figure: Torcular herophili Type II – SSS opens to right transverse sinus with hypoplastic anterior 3rd of SSS and hypoplastic left transverse and sigmoid sinus.

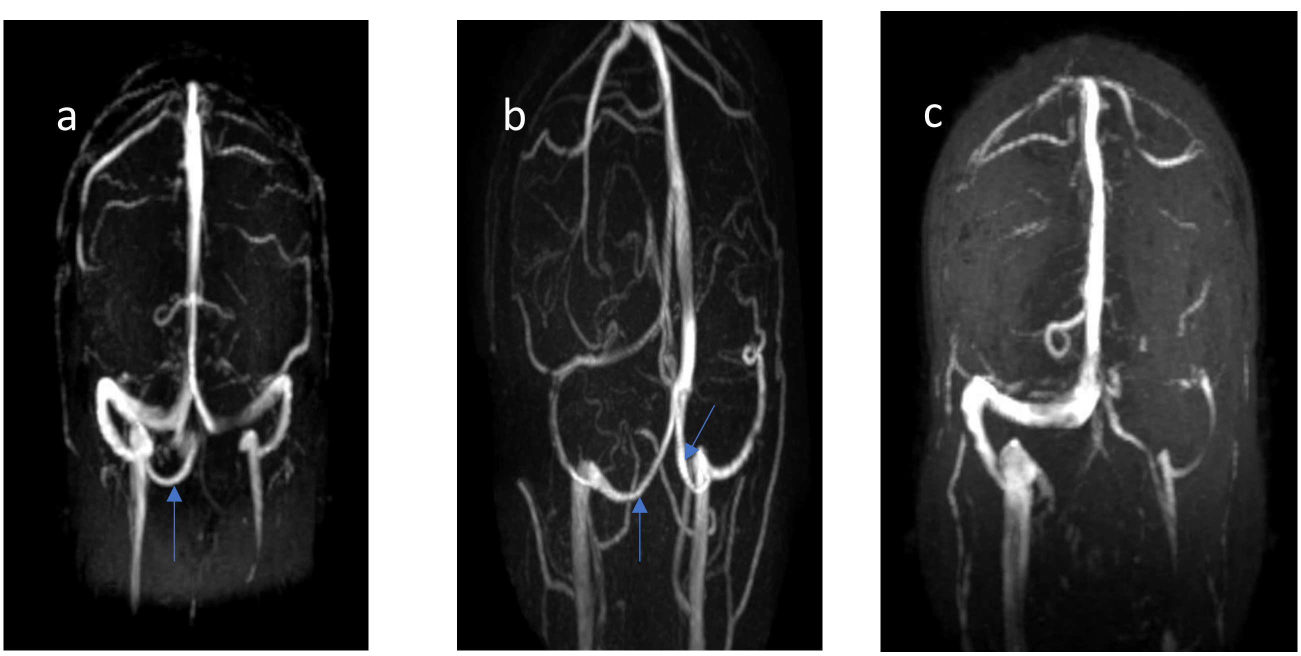


Figure:- a) Right occipital sinus b)Bilateral occipital sinus with bilateral hypoplastic transverse and sigmoid sinus c)Left occipital sinus with hypoplastic left transverse and sigmoid sinus

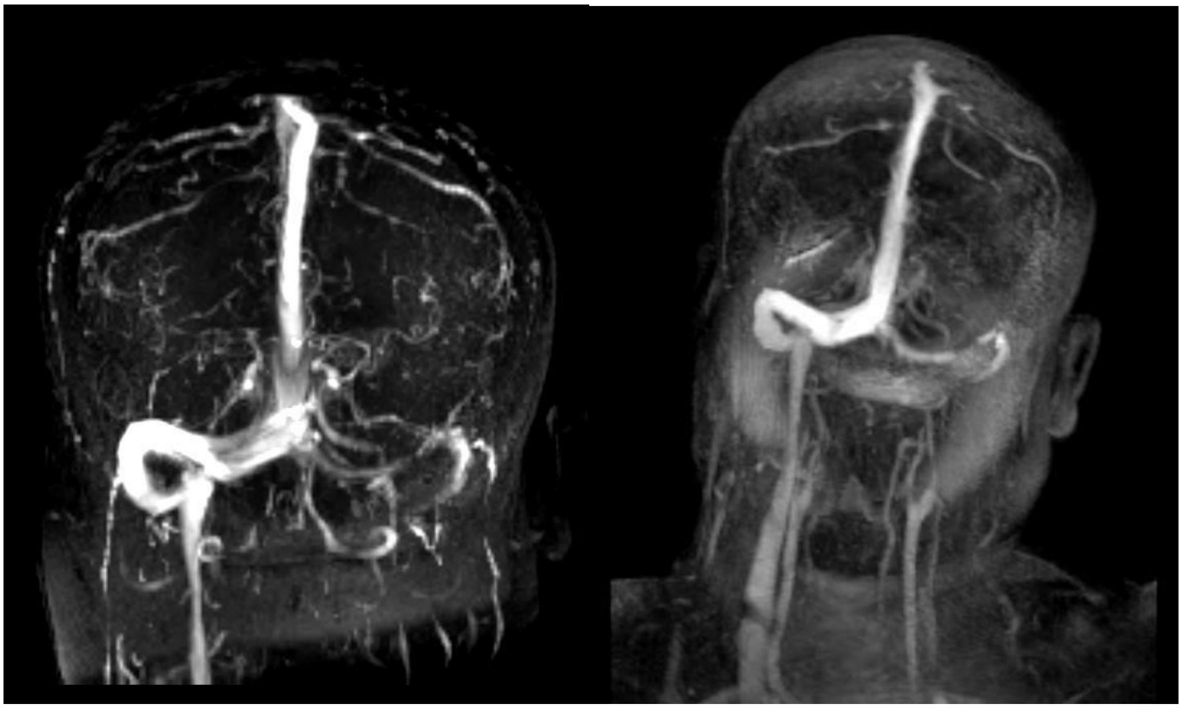


Figure:- Flow gap in left transverse sinus mimicking atresia, however on contrast MRV it shows hypoplastic left transverse and sigmoid sinus.

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