Clinical importance of imaging anatomical signs in predicting transverse sinus dominance using conventional magnetic resonance imaging

DOI: https://doi.org/10.32007/jfacmedbagdad.6511910.

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J Fac Med Baghdad
2023; Vol.65, No. 1
Received: April, 2022
Accepted: Feb., 2023
Published: April 2023

Abstract:

Background: Differentiating flow gaps associated with hypoplastic transverse sinus from venous thrombosis is a diagnostic challenge in brain magnetic resonance imaging with venography.

Aim of the study: To assess the clinical benefit of anatomical signs to anticipate the side of the dominant transverse sinus.

Patients and Methods: A total of 100 patients underwent brain magnetic resonance imaging with venography at the radiology department /medical city and were retrospectively reviewed for the direction of superior sagittal sinus flow void, inclination of sulcus for the superior sagittal sinus, angulation of the posterior falx and direction of occipital lobe bending in axial non-contrast T1 weighted image, then compare these findings with a side of the dominant transverse sinus in magnetic resonance venography.

Results: Inclination of sulcus for superior sagittal sinus and superior sagittal sinus flow void direction toward the right side had high positive predictive values (95.5%) and (93.2 %) in proper matching with the right transverse sinus dominance, respectively. Right-sided angulation of the posterior flax and rightward direction of the occipital lobe had a positive predictive value of (90.9 %) in predicting transverse sinus dominance.

Conclusion: The side of dominant transverse sinus can be anticipated by reviewing anatomical signs in T1 weighted image, which may help to differentiate hypoplastic transverse sinus from venous thrombosis that aid in better interpretation of brain MRI- MRV examinations.

Keywords: Hypoplastic transverse sinus, occipital lobe bending, occipital petalia, posterior falx angulation, transverse sinus dominance.

Introduction

Thrombosis of dural venous sinus is one of the leading causes of cerebral infarction and parenchymal hemorrhage. The superior sagittal sinus (SSS) and transverse sinuses (TSs) are the most frequently affected in cerebral venous thrombosis (1,2,3). It's more frequently observed in females compared to males (male to female ratio was 1:1.3) (4). Headache is the most common presenting symptom, while focal neurological deficit, papilledema, and seizure all are less common (5).

Asymmetrical caliber of TS is prevalent. Right TS dominance represents 59% of cases, while left TS dominance, and codominant (CD) TS have a prevalence of 10–29%, and 16–31%, respectively (6,7). It is also possible for one transverse sinus to be congenitally absent (if TS is atretic, the ipsilateral sigmoid sinus often receives drainage directly from the vein of Labbe). Epidemiological data, like age and gender, have no influence on the pattern of dominance of TS (8,9). Minimal changes during various embryological developmental stages can create anatomical variants which are frequently accompanied by changes in the organs that develop at similar stages. The illumination of the relationship between these anatomic variations might have an important clinical outcome, both from the diagnostic and therapeutic aspects (10). Therefore, asymmetry of the sigmoid sulcus on non-contrast brain computed tomography (CT) has been suggested as a measure to differentiate between TS thrombosis and an atretic sinus (11). occipital petalias where there is protrusion of one hemisphere relative to the other thereby causes an

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impression on the inner table of the skull. In many individuals, these can be easily observed on CT and MRI scans (12,13). Pettersson et al. (2018) have Suggested a possibility of an association between occipital bending and transverse sinus dominance (14). Therefore, direction of occipital bending might help the clinician to differentiate a venous thrombosis involving the transverse sinus from sinus hypoplasia by identifying the relationship between occipital bending and hypoplastic TS (10).Magnetic Resonance Imaging (MRI) has been widely used and become the mainstay in the investigation of suspected venous thrombosis and its sequalae. MRI offers multiple advantages which include its non-ionizing property, avoiding intravascular catheterization complications associated with CT venography and digital subtraction angiography with excellent contrast resolution that help to demonstrate and age thrombus precisely (15,16). Cerebral venous thrombosis evolves similar to a parenchymal hematoma because it consists predominantly of red blood cells and it appears as "loss of flow void" in spine echo sequences while in T2* weighted gradient-recalled echo (GRE) appears as exaggerated signal loss due to the presence of the hemosiderin and it is very useful in depicting thrombi in early stages. An absence of flow on MRV with a corresponding abnormal signal in a sinus is needed to diagnose venous sinus thrombosis (17, 18). Despite that, a number of pitfalls are encountered during interpretation of MRI sequences as, for example, an acute thrombus (in the first five days) will appear isointense on T1weighted image (WI) and hypointense on T2 WI. Therefore, it may be mistaken with normal flow void seen in patent sinuses on spin echo imaging (19,20). Contrast-enhanced MRV is also subjected to diagnostic errors in chronic dural sinus thrombosis which is changed into a fibrotic mass due to intra-thrombus fibroblast and capillary proliferation with multiple endothelia-lined channels within the thrombus, that is intensely enhanced; giving false impression of normality on contrast-enhanced sequences. Furthermore, chronic dural sinus thrombosis may lack blooming/susceptibility artifacts (as denatured hemoglobin is cleared from the organizing thrombus by macrophages), making the sequence unreliable in chronic cases (15). Interpretation of TOF (Time of Flight) - MRV is also had some potential diagnostic pitfalls. Of these technical artifacts, flow gaps seen in the non-dominant TS, slow or turbulent flow resulting in drop of signal in addition to arachnoid granulation that may cause filling defects within the sinus (2,15,21). As a result, physiologic hypoplasia or aplasia can be incorrectly diagnosed as sinus thrombosis, whereas Non-occlusive TS thrombus can be misinterpreted as a normal congenital asymmetry of TS caliber (7, 22).

Patients and Methods

A total of 100 patients underwent brain MRI – MRV examinations were reviewed, 68 of them (45 females and 23 males) had no pathology involving dural venous sinuses were included in a retrospective study in the period between December 2020 and March 2021 at MRI department of Baghdad teaching hospital and Gazi Al- Hariri hospital of medical city complex. The age range was between 10-81 year.

Cases, which were interpreted as dural venous sinus thrombosis (25 cases), those who had a surgery or lesions involving the dural venous sinuses (1 case), missing sequences (2 cases), lesions causing midline shift (1 case) and artifacts degraded the image and interfere with proper evaluation of cases (3 cases), were excluded from the study.

MRI Technique: Magnetic resonance imaging scanner of 1.5 tesla (Philips Achieva nova dual 16 channel) were used in which all patients were scanned in supine position with standard circularly polarized head coil. For each MRI- MRV examination, images from: Axial non-contrast enhanced T1WI spin echo at TR/ TE, 650/15, FOV: AP:230 mm, RL:183 mm, FH: 149 mm, slice thickness :5 mm, interslice gap 1mm , flip angle :69 degree and axial non- contrast enhanced TOF MRV at TR/TE: 15/10; FOV AP: 250 mm; slice thickness: 1.6 mm; intersection gap 0.3 mm , flip angle 10 degree . Sagittal MRV was reformatted from axial MRV data were reviewed and used for the measurement of the surface area of each transverse sinus.

- **T1WI:** In all cases the axial non- contrast enhanced T1WI is reviewed first focusing on the sulcus for the superior sagittal sinus short distance above the sinus confluence. The images were optimized to the reviewer's preference by magnification and windowing to facilitate detection of the sulcus for the superior sagittal sinus. The appearance of the inner table of the skull contacting the superior sagittal sinus was subjectively classified as concave, flat or of double concavities (figure 1)

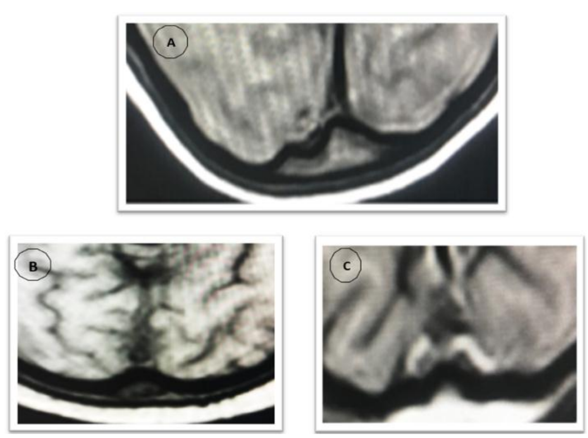

Figure (1): The appearance of the sulcus for superior sagittal sinus on the inner table of the skull: (A) concave shaped, (B) flat shaped and (C) double concavities

The angulation of the superior sagittal sinus sulcus was measured with the help of digital open-angle tool taking the posterior falx cerebri as a reference line, another line was drown touching the apices of the two bony peaks in cases of concave shaped sulcus or by following the slope of the sulcus in cases of being flat shaped. The sulcus was classified as rightward angulation if this angle was obtuse to the right, leftward if the angle was obtuse to the left, or no-angulation if the angle was 90°± 2° (Figure 2).

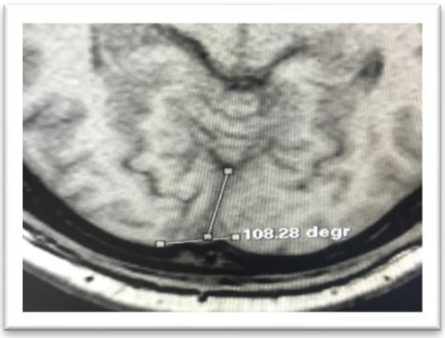

Figure (2): The sulcus for the superior sagittal sinus that is directed to the right (> 90° to the right).

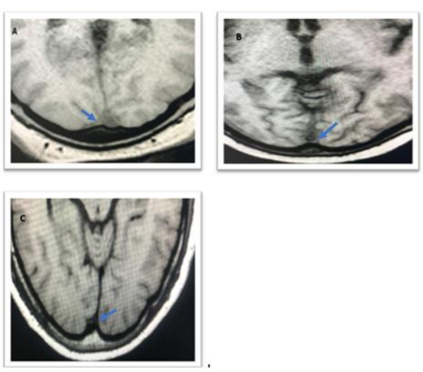

Figure (3): Laterality of the superior sagittal sinus A: leftward direction B: non- lateralized, C: rightward direction Direction of the inferior-most occipital lobe is evaluated subjectively by identification of the most inferior axial image showing the occipital parenchyma, which is termed occipital petalia and direction of the posterior falx angulation (Figure 4).

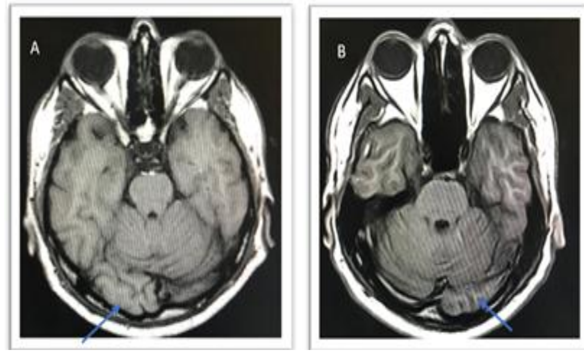

Figure (4): An axial non-contrast T1WI. The most caudal section showing occipital parenchyma the right occipital lobe appears at lower level than the left (A), left occipital lobe appears at lower level than right one (B) (blue arrows).

Angulation of the posterior falx cerebri is also assessed in relation to a line drown between frontal lobes passing between cerebral peduncles using digital open-angle, in which the tilt of the posterior falx was classified as rightward, leftward, or non-lateralized if the angle is obtuse but less than 180° to the right, obtuse less than 180° to the left and 180°± 2° respectively (Figure 5).

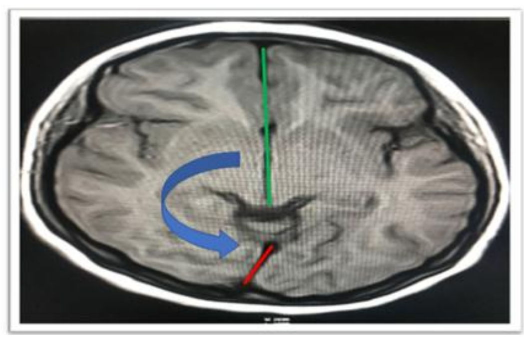

Figure (5): Rightward angulation of the posterior falx, a green line is the reference line between both frontal lobes and inter-peduncular fossa, the red line represents the posterior falx.

TOF- MRV

Laterality dominance of the transverse sinus was assessed objectively by measuring the cross-sectional area of each transverse sinus in the sagittal reformatted images using free hand tool after marking each transverse sinus in the axial images at 20 mm distance lateral to the sinus confluence to avoid inadvertent measurement of either the superior sagittal or sigmoid sinuses. If the difference between the cross- sectional areas of the two TSs was 5% or less from the summation of both surface areas, it is classified as "codominant "If the difference was more than 5%, it is classified as right or left dominant depending on which side had the larger cross-sectional area (Figure 6)

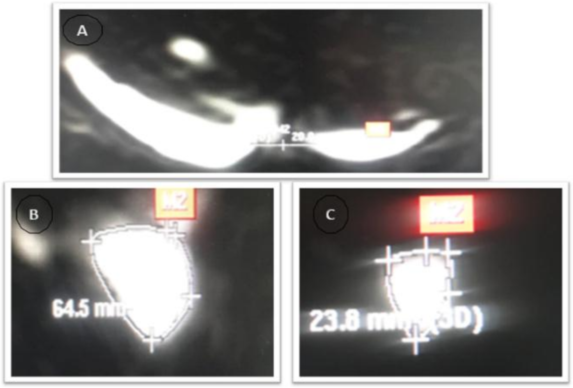

Figure (6): TOF- MRV shows right sided dominant transverse sinus: (A) axial image, (B and C) sagittal reconstructed images of right and left transverse sinuses

Statistical Analysis

Data were statistically analyzed using Statistical Package for Social Sciences (SPSS) software version 22 for windows. Descriptive statistics presented as mean± standard deviation (SD) and frequencies as percentages. Positive predictive values (PPV) of the four anatomic features of interest were calculated. Correlation was assessed using the Pearson correlation coefficient (*r*). The results were considered significant if *P* value was less than 0.05.

Results

Dominant right TS carries the highest frequency of occurrence which was seen in 44 of 68 (64.7 %), while dominant left TS was found in 18 of 68 (26.5%) and the co-dominant pattern is the least common pattern that was seen in only 6 out of 68 (8.8%). Right-sided inclination of sulcus for SSS had high PPV (95.5%), SSS flow void direction toward the right side had PPV (93.2 %) in proper matching with the right TS dominance. However, both right-sided angulation of posterior flax and rightward direction of the occipital lobe carries slightly lower PPV of (90.9 %) in correct prediction of TS dominance. Leftward bending of the posterior occipital lobe had PPV (83.3 %) in predicting left TS. Left-sided inclination of sulcus for SSS, leftward angulation of the posterior falx and SSS flow void direction all had (72.2 %) PPV in correct prediction of TS dominance.

Non-lateralized (NL) sulcus for SSS and (NL) SSS flow void were found in (11) and (12) patients, respectively, and only two cases were associated with co-dominant TS for each of the two groups. Fifteen patients showed non- angulated posterior flax, and equal occipital lobes were found in (13) patients, both of these findings correctly predict co-dominant TS in only one case. In addition, double channel arrangement of the SSS was seen in only two cases. The measurement of the inclination and flow void direction of SSS cannot be applied to double channel due to atypical morphology.

Table (1): Frequency and Positive Predictive Value of the Inclination of sulcus for superior sagittal sinus

	Frequency	Percent	PPV	P-value
Right	42	61.8	95.5	<0.001
Left	13	19.1	72.2	<0.001
Non-lateralized	11	16.2	NA	NA
Double channel	2	2.9	NA	NA
Total	68	100.0		

*** NA: non- applicable.**

Table (2): Frequency and Positive Predictive Value of the Angulation of posterior falx

	Frequency	Percent	PPV	P-value
Right	40	58.8	90.9	<0.001
Left	13	19.1	72.2	<0.001
No angulation	15	22.1	NA	NA
Total	68	100.0		

*** NA: non- applicable.**

Table (3): Frequency and Positive Predictive Value of the Superior sagittal sinus flow void directions

	Frequency	Percent	PPV	P-value
Right	41	60.3	93.2	<0.001
Left	13	19.1	72.2	<0.001
Non lateralized	12	17.6	NA	NA
Double channel	2	2.9	NA	NA
Total	68	100.0		

***NA: non-applicable**

Table (4): Frequency and Positive Predictive Value of the Direction of inferior most occipital lobe

	Frequency	Percent	PPV	P-value
Rightward	40	58.8	90.9	<0.001
Leftward	15	22.1	83.3	<0.001
Equal	13	19.1	NA	NA
Total	68	100.0		

***NA: non-applicable.**

Discussion:

Routine MRI sequences and MRV are frequently used to evaluate and quantify flow within the dural sinuses. (23, 24) Although non-contrast TOF-MRV can detect slow flow, but it can do so to a certain extent. The short interval radio-frequency pulses saturate spins flowing faster than this limit, resulting in signal loss, also known as "flow gap." a phenomenon that is further exacerbated by coplanar acquisition and mainly seen in hypoplastic dural sinuses, flow gaps were demonstrated in 31% of non-dominant TSs in a study performed by Ayanzen et al. (2000) (25) The uneven venous drainage pattern of TSs is well-recognized and studies concerning of venous drainage patterns of cerebral hemispheres revealed that the flow was towards the right TS in the majority of cases (26). In this study, the measurement or observation of the side of direction of the four examined anatomical signs in addition to the method of measurement of cross-sectional area of each TS depended on a methodology described by Pettersson et al. (2018) (14). The inclination of the sulcus for SSS and the direction of the SSS flow void has a high PPV for predicting the direction of dominant TS and it's easily applicable using T1WI. Almost similar results found in a comparative study performed by Pettersson et al. (2018) (14). SSS sulcus sloping to the left, posterior falx angulation to the left and SSS flow void direction, all had a moderately high PPV (72.2 %) in correctly predicting TS dominance which carries lower PPV than right-sided arrangement of these signs which carries (95.5%) PPV for SSS sloping to the right and (93.2%) PPV for the SSS flow void direction to the right. Another finding is the relationship between petalia related features and TS asymmetry that carries PPV of (90.9 %) and (83.3 %) in predicting right and left dominant TS, respectively. In a study performed by Pettersson et al. (2018) showed nearly similar results and it has been postulated that left TS could be exposed to extrinsic compression during development by caudal positioning of the left occipital lobe that may contribute to sinus hypoplasia (14). However, a study performed by Arsava et al.(2018) (10) revealed lower PPV compared to current study. This difference is probably attributed to a variable method of TS size measurement as Arasava et at. (2018) depended on visual estimation of the size of TS and dimension of sigmoid notch on each side in T2WI to determine the side of dominant venous drainage. The relative difference in measurements between both TS in each MRV sample (using axial acquisition TOF-MRV) was more important in this study than the absolute sinus cross-sectional area; therefore, inaccuracies attributed to the TOF technique with the chance of having loss of flow-related bright signal are unlikely to have had a significant impact on the outcome of the study. Nevertheless, contrast enhanced MRV is more accurate to represent the cross-sectional area and sagittal acquisition TOF- MRV is another option shows better depiction of the TS cross-sectional area which was not available in the protocol of the study center. Involvement of patients instead of normal asymptomatic subjects is considered a limitation. In addition, despite exclusion of cases that interpreted as positive for venous thrombosis and all MRI sequences were reviewed, still, there is a small possibility of involvement of false negative results.In addition to the above-mentioned, the study did not involve infants and neonates due to the unavailability of cases in the study center. Finally, multiple anatomic features of interest were apparent on the same image during analysis of the axial T1WI, a factor which cannot be avoided, but may result in measurement bias. In addition, for each patient, the MRV analysis came immediately after the T1WI review. Each of these variables may have affected the authors findings. Another potential limitation is the head position during scanning would have an effect on which occipital lobe was classified as the most inferior.

Conclusion : Right or left TS dominance can be anticipated from the direction of SSS flow void, the slope of the bony peaks for sulcus of SSS, angulation of the posterior falx, and direction of bending of the posterior occipital lobe on non-contrast T1WI that may help better interpretation of brain MRI -MRV examinations especially when intra venous contrast cannot be given like in pregnant women and patients with renal impairment.

Authors' declaration:-

Conflicts of Interest: None.-

We hereby confirm that all the Figures and Tables in the manuscript are ours. Besides, the Figures and images, which are not ours, have been given permission for re-publication attached with the manuscript.-Authors sign on ethical consideration's approval-Ethical Clearance: The project was approved by the local ethical committee in Arab Board of health specializations according to the code number 941/2021 , at 31/5/2021

Author's contributions:

Dr. Maryam I. Al-Ani: data collection, formal analysis & writing original draft

Dr. Qusay A. Fahed : substantial role in the research concept, methodology training, supervision, reviewing and editing draft

Dr. Ali I. Shyaa supervision, reviewing and editing draft

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How to Cite
AL-Ani maryam, A. Fahed Q, I. Shyaa A. Clinical importance of imaging anatomical signs in predicting transverse sinus dominance using conventional magnetic resonance imaging. JFacMedBagdad [Internet]. 2023 Apr. 27 [cited 2023 May 10];65(1):14-9.

اهمية العلامات التشريحية لتنبأ اتجاه سيادة الجيوب الوريدية المستعرضة بأستعمال الرنين المغناطيسي

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الخلفية : تعرض تصوير الجيوب الدماغية الوريدية عند استعمال الرنين المغناطيسي للتحديات التشخيصية لتفرقة الضمور الخلقي عن الخثر الدموية .
الغرض: تقييم قدرة العلامات التشريحية على توقع اتجاه سيادة الجيوب الوريدية المستعرضة اثناء فحص الرنين المغناطيسي للدماغ.
الطريقة والنتائج : اجري الفحص على مائة مريض اثناء فحص الرنين المغناطيسي للدماغ المتضمن تصوير الجيوب الوريدية وملاحظة اتجاه تدفق الجيب السهمي العلوي و اتجاه انحناء اخدود الجيب السهمي العلوي واتجاه انحراف المنجل السحائي الخلفي واتجاه انحناء الفص الخلفي للدماغ. حيث شكل اتجاه تدفق الجيب السمهي العلوي و اتجاه انحناء اخدود الجيب السهمي العلوي نحو اليمين اعلى نسبة توقع صحيحة لسيادة الجيب الوريدي المستعرض.
الاستنتاج : اظهرت العلامات التشريحية قدرة جيدة على توقع اتجاه سياده الجيوب الوريدية المستعرضة.
الكلمات المفتاحية: ضمور الجيوب الوريدية المستعرضة, انحناء الفص القذالي, البتلة القذالية, انحناء منجل المخ الخلفي, سيادة الجيوب الوريدية المستعرضة.