

Normal variations in cerebral venous anatomy and their potential pitfalls on 2D TOF MRV examination: Results from a private tertiary care hospital in Karachi

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Abstract

Objective: To assess normal venous anatomy of the cranium and its anatomical variants.

Methods: This retrospective study was conducted at Radiology Department of Dr. Ziauddin Hospital, Karachi, and comprised data of patients aged 2-75 years and having undergone magnetic resonance imaging of brain from April 2015 to April 2016. Magnetic resonance venography was reviewed to evaluate the cerebral venous system.

All magnetic resonance venography examinations were performed using a contiguous two-dimensional time-of-flight venography technique, and were reviewed by two consultant radiologists.

Results: Out of 204 patients, 96(47.05%) were males and 108(52.94%) were females. Overall Magnetic Resonance Venography examinations were found to be normal in 94(46.07%), patients, while 110(53.92%) had some of the normal anatomical variants. There was presence of superior sagittal sinus and straight sinus in 204(100%) cases. Inferior sagittal sinus was seen in 179(86.05%). Transverse sinus was hypoplastic in 8(3.92%) on the right and 80(39.2%) on the left side. Hypoplastic sigmoid sinus was present in 51(25%) patients and aplastic sigmoid sinus in 2(0.98%) patients. Flow gaps were also observed in 22(10.78%) patients. Occipital sinus was identified in 17(8.3%), vein of Trolard in 98(48.03%) and vein of Labbe in 105(51.47%).

Conclusion: Two-dimensional time-of-flight magnetic resonance venography examination was found to be a useful imaging tool showing great sensitivity in determining the normal cerebral venous anatomy.

Keywords: Cerebral, Venous system, Normal variants, Anatomical, Magnetic resonance imaging. (JPMA 68: 1009; 2018)

Introduction

Venous system of brain is a complex system that is different than the rest of the body parts as it does not follow the typical cerebral arterial system. It consists of superficial and deep cerebral veins and dural sinuses. The cerebral veins coursing beneath deep surface of arachnoid matter are further drain to the nearest dural venous sinuses. Superficial cerebral veins are alienated into three categories; dorsomedial, ventrolateral and anterior groups that drain into superior sagittal, lateral and cavernous sinus, respectively. Superior sagittal sinus, the largest dural venous sinus, runs in sagittal plane and drains most of the blood from the surface of both cerebral hemispheres. It also receives blood from diploic, meningeal and emissary veins. Deep cerebral veins drain the deeper parts of cerebral hemispheres into straight sinus, lateral and sigmoid sinuses. Venous blood from orbits, inferior aspects of parietal and frontal lobes are drained into cavernous sinus. The superior and inferior petrosal sinuses are also drained into cavernous sinus. These sinuses also drain into internal jugular veins.¹ The draining venous system of posterior fossa has significant variations. They are characterised into superior, anterior

and posterior groups that drain into galenic system, petrosal and transverse sinus, respectively.

Dural venous sinuses are located between the two layers of dura mater. It is also vital to recognise the arrangement and pathophysiology of venous channels in addition to their structure. Both cerebral veins and dural sinuses are valve-less and have no tunica muscularis that allows the veins to expand and remain dilated in response to even extended occlusion. As they lack valves, venous blood can flow in both directions, causing intracranial spread of infected blood from scalp and mastoid air cells. Among other dural sinuses, superior sagittal sinus has greater prevalence of thrombosis as cortical venous blood drains against the flow of blood in this sinus causing turbulence which further increases by presence of internal septations at the inferior angle of sinus. The dural sinuses contain arachnoid villi and granulations, which are responsible for cerebrospinal fluid (CSF) absorption. These arachnoid villi and granulations are blocked after dural sinus thrombosis leading to the development of papilledema and intracranial hypertension.²

Various invasive and non-invasive imaging tools are available to assess the venous system. In non-invasive methods, magnetic resonance venography (MRV) is preferable as there is no risk of ionising radiation. It is less

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time-consuming and relatively less dependent on operator. MRV is further divided into bright-blood and dark-blood techniques. Two-dimensional time-of-flight (2D TOF) is non-contrast bright-blood MRV technique which relies on inflowing blood to provide vascular signal. TOF provides an excellent structural evaluation for the recognition of vascular stenosis and estimation of blood flow through major veins. The pulse sequences of TOF are gradient-echo or spoiled gradient-echo, that are performed sequentially. All phase-encode steps are carried out in a single slice before moving on to the next slice that results in more suppression of stationary tissue. Blood flowing into the slice is not saturated and appears bright relative to the suppressed dark background. MRV is a very useful modality in evaluating cerebral venous anatomy and to determine the normal anatomical variants. Being a non-contrast technique, it can safely be used in renal insufficiency patients or with contrast allergy. It is efficacious in diagnosing dural sinus thrombosis in pregnant women.³

The use of cerebral MRV is increasing in frequency as a non-invasive means of evaluating the intracranial venous system to assist the interpretation of these examinations and thus to help avoid potential pitfalls in the diagnosis.⁴ The current study was planned to evaluate the intracranial venous anatomy and its normal anatomical variants in our population by using 2DTOFMRV.

Patients and Methods

This retrospective study was conducted at Radiology Department of Dr. Ziauddin Hospital, Karachi, and comprised data of patients aged 2-75 years with no regard to and having undergone brain magnetic resonance imaging (MRI) from April 2015 to April 2016. The MRVs of the patients were reviewed to evaluate the cerebral venous system. Patients with any abnormality on MRI brain examination, or previous history of surgery and neuro-intervention, were excluded.

All MRVs were performed using a contiguous 2D TOF MRV technique on Siemens Avanto 1.5-Tesla MRI scanners. Time of Repetition / Time of Excitation (TR/TE) was 50/8.4 and a Flip angle of 60° was used. Images were acquired in coronal and sagittal planes with a slice thickness of 1.5mm. Field of view was 210mm with a matrix size of 256mm x 128mm. Maximum pixel intensity projection (MIP) method was used for post-processing of source images. MRVs were reviewed by two consultant radiologists in the Picture Archiving and Communication System (PACS) workstation using high-resolution monitors. Each case was systematically reviewed to

properly evaluate the venous system. Keen importance to the source images was given to reduce the diagnostic error and potential pitfalls. The transverse sinuses, sigmoid sinuses, occipital sinus, superior and inferior sagittal sinuses and the major intracranial veins, including the veins of Trolard and Labbe were assessed using a schematic approach.

All venous sinuses were reviewed for their presence or absence. A sinus was considered absent or aplastic if it was not completely visualised. The transverse and the sigmoid sinuses were compared with size of superior sagittal sinus. If size of the transverse and sigmoid sinus was found to be half of the linear measurement of superior sagittal sinus, it was considered hypoplastic. Flow gaps and arachnoid granulations were also studied.

Results

Out of 204 patients, 96(47.05%) were males and 108(52.94%) females. Overall MRVs were normal in 94(46.07%) patients, while 110(53.92%) had some of the normal anatomical variants.

Superior sagittal sinus and straight sinus were seen in all 204(100%) patients studied. Inferior sagittal sinus was seen in 179(86.05%) patients (Table-1).

Right transverse sinus was hypoplastic in 8(3.92%)

Table-1: Summary of results showing Percentages (%) of normal occurrence of dural venous sinuses.

Sinuses	Occurrences %
Superior Sagittal Sinus	(204) 100%
Inferior Sagittal Sinus	(179) 86.05%
Internal Cerebral Vein	(92) 45%
Straight Sinus	(204) 100%
Occipital sinus	(17) 8.3%
Vein of Trolard	(98) 48.03%
Vein of Labbe	(105) 51.47%
Vein of Galen	(132) 64.7%

Table-2: Summary of results showing occurrence of normal anatomical variants in Dural venous Sinuses.

Normal Variants	Occurrences %
Hypoplastic	
Right Transverse Sinus	(8) 3.92%
Left Transverse Sinus	(80) 39.2%
Right Sigmoid Sinus	(6) 2.9%
Left Sigmoid Sinus	(45) 22.05%
Aplastic	
Left Sigmoid Sinus	(2) 0.98%
Flow Gaps & Arachnoid Granulations	(22) 10.78%

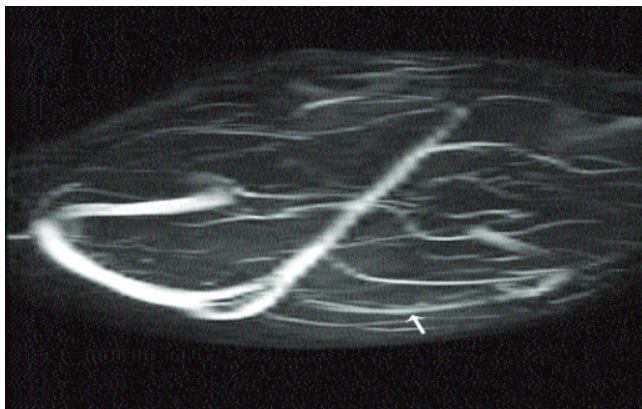


Figure: Hypoplastic left transverse and sigmoid sinuses.

patients, and of them 2(25%) were found in males and 6(75%) in females. Left transverse sinus was hypoplastic in 80(39.2%) patients, and was common in both genders; - 19(19.6%) and 21(19.6%), respectively. Hypoplastic sigmoid sinus was present in 51(25%) patients, and of them 6(2.9%) were on the right side and 45(22.05%) on the left side. Aplastic sigmoid sinus was found in 2(0.98%) patients.

In 17(8.3%) patients, occipital sinus was present with a male preponderance. Vein of Trolard was found in 98(48.03%) patients of whom 44(44.89%) were present on the right side and 54(55.1%) on the left side. The vein of Labbe was found in 105(51.47%) patients with 80(76.5%) on the left side. Vein of Trolard and Labbe were predominantly common in females. Vein of Galen was found in 132(64.7%) and internal cerebral veins in 92(45%) cases.

The flow gaps and arachnoid granulations were also observed in 22(10.78%) patients (Table-2).

Discussion

A number of different anatomical and pathologic conditions can influence and determine abnormalities in venous drainage. Due to this complexity, often only a multimodal approach can succeed in providing a final diagnosis. A combination of MRI and MRV sequences may be a successful approach to study different types of venous pathologies or para-physiological conditions that could alter blood drainage.

Zivadinov et al.⁵ classified venous drainage anomalies into intra- and extra-cranial which can be further characterised into intra- and extra-luminal pathologies. Pathologies of internal vessel wall such as abnormal valves, flaps, septa and webs are considered intra-luminal and these are usually difficult to detect with MRIs. The

most common extra-luminal abnormality includes more than 50% reduction in vessel calibre.

Recent advancement has increased the diagnostic yield of MRI for neurovascular anatomy and pathologies. MRV examination is frequently used nowadays to assess the venous system. It has out-dated the old technique of conventional angiography to assess the venous abnormality as it is cheaper and widely available. It is a non-invasive technique without risk of intervention-related complications. It can be performed simultaneously with MRI brain imaging in short acquisition time. It is a safe diagnostic modality with no radiation hazards and can be done in young individuals and pregnant females.⁴

The 2D TOF is a useful technique of MRV, which is used to assess the intracranial venous system. Because of its outstanding sensitivity to slow flow and the diminished sensitivity to loss of signal from saturation effects, it is compared with three-dimensional TOF techniques.⁶ Two-dimensional techniques are most sensitive to flow that is perpendicular to the plane of acquisition, the coronal, axial or an oblique plane are often used for image possession. Venous flow in the plane of image acquisition may cause saturation and resultant nulling of the venous signal at TOF MRV, a probable drawback for image interpretation and analysis. Close evaluation of source images is compulsory to precisely assess venous morphologic features and diminish the potential for diagnostic error. In a study conducted by Liauw et al.,⁷ three dimensional phase-contrast MRV was also found to be equally sensitive for detecting venous anatomy.

In this study, normal intracranial venous anatomical variants were observed in patients who had normal MRI brain examination. Patients with any abnormality on MRI brain examination were excluded from the study. Statistical Analysis of the results showed that most of the patients (53.92%) had some anatomical variant, rest of the patients (46.07%) showed normal MRV examination.

Occurrence of superior sagittal sinus and straight sinus were persistent in all the patients. Inferior sagittal sinus was seen in majority of cases (87.05%), but not visualised in all MRV examinations. Ayanzen et al.⁸ showed presence of inferior sagittal sinus in 52% of cases.

Hypoplastic transverse and sigmoid sinuses were frequently encountered in the study as shown in. The transverse sinus was found to be hypoplastic in 88(43.13%) patients. They were more frequent on left side (39.2%) than on the right side (3.92%) (Figure). There was a variation in gender distribution, with hypoplastic right transverse sinus found

to be more common in females, however, hypoplastic left transverse sinus was equally found in both males and females. In a study done with conventional angiography, transverse sinus was partially or completely absent in 20% of the cases, while the asymmetric transverse sinuses were seen in 49% of cases. In the majority of cases, right transverse sinus was bigger than the left.^{9,10} In another study by Alper et al.,¹¹ the left transverse sinus was relatively hypoplastic in 39% and aplastic in 20%. The right transverse sinus was aplastic in 4% of cases and relatively hypoplastic in 6%. This study also concludes hypoplastic transverse sinus predominantly on the left side. Sigmoid sinus was found to be hypoplastic in 51(25%) patients, while only two patients had aplastic sigmoid sinus.

The occipital sinus originates from the primitive torcular plexus.¹² Ayanzen et al.⁸ reported occipital sinus in 10% while Lang J¹³ reported in 35.5% of cases. Ruiz et al.,¹⁴ reported it in one of 12 cadaveric patients and Widjaja et al.,⁹ reported it in 18% of the cases. In our study, occipital sinus was identified in 17 patients (8.3%). Vein of Trolard was found in 98 patients and vein of Labbe in 105 patients.

The internal cerebral veins run posteriorly in the roof of third ventricle and join under the splenium of the corpus callosum to form the great cerebral vein. The vein of Galen is a short (1-2cm long), thick vein that passes posterosuperiorly behind the splenium of corpus callosum in the quadrigeminal cistern. It receives the basal veins and the posterior fossa veins and drains to the anterior end of the straight sinus where this unites with the inferior sagittal sinus. Internal cerebral vein was present in 45% and Vein of Galen in 64.7% of cases in this study.

The majority of flow gaps on 2D TOF MRV on the posterior aspect of superior sagittal and transverse sinuses were possibly associated with saturation of in-flow or intra-voxel dephasing rather than a true anatomic hypoplasia of the venous sinuses. Blood signal intensity is high when the imaging plane is perpendicular to the course of blood flow. Saturation is induced if blood flow is parallel to the imaging plane. Because the bulk of the intracranial venous flow is in the anteroposterior direction, section acquisition in the coronal plane 2D TOF MRV allows improved visualisation of most of the cerebral venous sinuses.⁹ In this study, flow gaps were observed in 22(10.78%) patients and were mostly found in posterior part of superior sagittal sinus and near torcularherophili (Table-1). Appearance of flow gaps on TOF MRV examinations as many as 31% had been reported. Alper et al.¹¹ stated flow gaps in 24%. Ayanzen et al.⁸ reported, 31% flow gaps in the transverse sinus, of them 90% were in the non-dominant sinus. A recent study done on Nepalese population¹⁵ using low field magnet of 0.35T concluded

that most of the flow gaps were found in transverse sinus 47% predominantly in non-dominant side. In only five cases out of hundred they detected unilateral flow gap in sigmoid sinus. Occipital sinus was found in 4%, vein of Labbe in 8% and basal vein of Rosenthal in 34% of the cases.

In order to accurately interpret MRV and to avoid probable pitfalls in analysis, one should be aware of the technical restrictions of 2DTOF imaging itself. Slow intravascular blood flow gives rise to flow gaps which is a potential pitfall in diagnosing venous thrombosis. In-plane and complex blood flow also give artefacts. Proper post-processing technique is also very important in minimising these technical limitations. Slice thickness needs to be set as smaller as possible i.e., 1.0 to 1.5 millimetres to overcome this issue.⁸

Loss of signal intensity can also result from intra-voxel spin phase dispersion because of a wide range of flow velocity in the voxel, higher orders of motion, and heterogeneity of the magnetic field. Intra-voxel dephasing can be reduced using smaller voxels, shorter TE, and flow compensation.⁶ TOF sequences with shorter TEs have reduced extent of spatial encoding sequence gradients and are therefore less sensitive to high-order motion that leads to better assessment of stenosis.¹⁶ Smith et al.¹⁷ proposed that TOF MR angiography with TE of 5.1 ms improved signal intensity recovery compared with TE of 6.5 ms. This effect was more prominent in children than in adults. Therefore, these authors have suggested the use of a shorter TE TOF MR angiography especially in children to improve signal intensity recovery and diagnostic assessment.

There are also some variations in the venous sinuses signal intensity due to slow flow of blood that appears as high signal intensity on conventional MRI.¹⁸⁻²⁰ The stagnant blood typically appears iso-intense on T1 and hyper-intense on T2-weighted images. Transverse sinus, sigmoid sinus and jugular bulb can normally show asymmetric signal intensity and enhancement and is more frequent on left due to compressive effect of left brachiocephalic vein during respiratory cycle.²¹

Arachnoid granulations are normal structures that protrude into the dural sinus lumen or lateral lacunae. Arachnoid granulations may closely mimic venous sinus thrombosis and therefore it is important to differentiate these two different entities. Arachnoid granulations typically appear as focal filling defects with a specific anatomic distribution. These are frequently present in transverse and superior sagittal sinuses as we found in this study. Although arachnoid granulations are a normal anatomic structure, if they are large and appear in the dominant sinus or only in

the transverse sinus, they may cause venous obstruction and leading to venous hypertension.²²

Significance of gender difference of intracranial venous sinuses anatomy is not known. In a study done by Gaurav et al.²³ females were more likely to have symmetrical transverse and sigmoid sinuses than males. Males had more hypoplastic left transverse sinus compared to females. In this study, hypoplastic transverse sinus was more prevalent in females on right side and equally common in both genders on left side. However, hypoplastic sigmoid sinus was frequently found in males.

2D TOF MRV examination is a non-invasive and safe diagnostic technique in evaluating intracranial venous anatomy and anatomical variants. This study highlights the normal variants of venous system in our population. Superior sagittal sinus, straight sinus and internal cerebral veins are consistently seen on MRV with slight variation of inferior sagittal sinus. Transverse and sigmoid sinuses are most commonly hypoplastic with a predilection of left side. Flow gaps and arachnoid granulations are the major pitfalls mimicking venous sinus thrombosis and must be carefully evaluated.

The single-centre nature of the current study and its small sample size were limitations. Furthermore, MIP post-processing algorithm used in 2D TOF MRV has its own limitation to underestimate vascular calibre which corresponds to over-estimation of vessel stenosis. Despite the shortcomings, 2D TOF MRV examination is a very useful imaging tool.

Conclusion

The 2D TOF MRV was found to be a useful imaging tool showing great sensitivity in determining the normal cerebral venous anatomy. It is important in depicting the normal variants and to evaluate the potential pitfalls. Knowledge of normal anatomical variants and pitfalls is imperative in interpreting cerebral MRV examination.

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Conflict of Interest: None.

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