

Original article:

Role of magnetic resonance venography in assessment of the intracranial venous sinus thrombosis

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Abstract

Cerebral venous thrombosis is a relatively uncommon but serious neurologic disorder that is potentially reversible with prompt diagnosis and appropriate medical care. The study was conducted on 50 patients with cerebral venous sinus thrombosis and subjected to MRI and MRV. This study included 50 patients with age range from 15 years to 70 years old and mean age of 34.70 years. Sixteen patients (32%) were female and thirty four patients (68%) were male. The most common and earliest clinical presentation in this study was headache. MRI features in this study were observed in the form of parenchymal changes and abnormal signals in thrombosed veins and sinuses in both T1 and T2, in addition to blooming and collaterals formation. The most common non-visualized sinus in the study group was SSS noted in 33%. MRI is sensitive in diagnosing both direct signs (evidence of thrombus inside the affected veins) and indirect signs (parenchymal changes) of CVST.

Key words: Magnetic resonance imaging, Venous sinus thrombosis, venous stroke, Magnetic resonance venography

Introduction

In last few decades there have been tremendous recent advances in development of Magnetic Resonance Angiography (MRA) for depicting vessels and blood flow as well as evaluating the occurrence of various cerebrovascular diseases. Though, most of advances have been made in field of arterial magnetic resonance angiography. On the other hand MRI of venous system of brain (based on susceptibility weighted imaging approach-SWI approach) is also important and offers new helpful insights into venous lesions and diseases. Also has been seen that neurologists and neuro-radiologists are paying active attention to the role of intracranial venous system (ICVS) in cerebrovascular diseases.

Till now ICVS has been evaluated traditionally during venous phase of conventional catheterized Digital subtraction angiography (DSA) as gold standard investigation for analyzing intracranial venous anatomy and a definite diagnostic tool for intracranial venous pathologies. Although being a gold standard technique DSA is still an invasive procedure with associated risks such as cerebral infarction, vascular wall injury and hematoma at puncture site[1]. Radiation exposure, allergic or nephrotoxic effects of iodinated contrast medium, limitation of 2-Dimensional (2D) planar imaging are additional disadvantages[2]. Therefore, the use of non-invasive techniques is a need for evaluation of

intravascular system. Various non-invasive techniques available are-

- CTV - Computed Tomographic Venography
- MRV - Magnetic Resonance Venography

CTV is more preferred over MRV due to its widespread availability and much faster image acquisition that reduces the patient related motion artifacts. However CTV is similar to catheter DSA due to need of iodinated contrast and radiation exposure; it also needs complex post-processing to remove bony structures from reconstructed images. Thus visualization of skull base structures is limited. Therefore CTV provides more of supportive role than MRV; which is proved to be more reliable [3].

Also CTV provides false positive results in patients with

- Sub-arachnoid & subdural hemorrhage as well as subdural / epidural abscess causing Empty Delta Sign.
- Filling defects in the sinus like prominent arachnoid granulations, CSF space.

Though MRV has some disadvantages like decreased spatial resolution, lower sensitivity and specificity for vascular patency, artifacts and potential diagnostic pitfalls.

Good correlation has been shown between MRV and DSA but there are 3 MRA methods commonly available for evaluating intravascular system:

- 2-Dimensional (2D) Time Of Flight (TOF)*
- 3-Dimensional (3D) Phase-Contrast*
- 3D Gadolinium – Enhanced (GE) Pulse sequences

2D TOF and 3D phase – contrast are the usually performed methods.

Cerebral venous (CVT) / cerebral venous sinus thrombosis (CVST) has been recognized since the early 19th century but still remains a diagnostic and

therapeutic challenge. Cerebral vein and sinus thrombosis is rare compared to arterial stroke that often occurs in young individuals. CVT may occur at any time from infancy to old age most reported cases were women in association with puerperium. Onset of symptoms may be acute/sub-acute/ chronic. Cerebral venous infarction is the most serious consequence of cerebral venous thrombosis. Venous infarcts are often multifocal bilateral affecting both grey matter and sub cortical white matter[4].

Review of literature

Progressively there has been increase in use of cerebral MRV as non-invasive method of choice for ICVS (Intracranial Venous System), particularly for imaging of the venous sinuses for diagnosing thrombosis, which at times proves to be difficult. [5] Not only the thrombosis in sinuses alter the normal anatomy and its appearance but also the occurrence of thrombosed veins, bleed, developmental anomalies etc. that may generate alterations.

Disorders like Idiopathic intracranial hypertension (ICHH) can cause alteration by compression over venous system, likewise in cases with congenital developmental anomalies such as stenosis etc.[6]

CVT is an uncommon cause of stroke among the young; but is being recognized frequently nowadays. A pro-thrombotic risk factor is identified in majority of the patients. MRI has improved the ability in diagnosing the condition; however the variability of radiological and clinical presentation remains a challenge. MR brain when combined with venography is the single most sensitive and non-invasivediagnostic technique of choice. The improvement in imaging technology with awareness among the clinicians and radiologists has

however led to the diagnosis being considered more often.

As the clinical course and the radiological findings are both highly variable, the difficulty in diagnostics still-persists.

Magnetic Resonance (MR) imaging has assumed the central role in the diagnosis and follow-up of the patients.

Venous strokes as compared to arterial strokes are primarily a disease in young population, with adults and children being affected often. Pro-thrombotic risk factors can be identified in approximately 85% of patients, three quarters of the adult patients being women. This increased risk seems to be entirely associated to oral contraceptive use and in peri/post partum period.

TOF MR Angiography (MRA) is based on the principle of flow – related enhancement and highlights the difference in magnetization between nuclei in flowing blood and those in stationary tissue. [7]

Materials

This study was approved by our institutional review board. In this study so far 50 patients have been prospectively taken with suspicion of Intra-cranial vascular lesions & were referred to radiology department for MRI Brain with venography irrespective of age and sex.

Inclusion criteria:

Clinically suspected cases of intra-cranial vascular lesions who are referred to radiology department for MRI brain with Venography, irrespective of the age and sex.

Exclusion criteria:

- Patients with history of metallic implant, foreign body, pacemaker, aneurysm clip, recently implanted prosthetic valve.

- Patients who are unstable to undergo MRI (e.g.-patients on ventilator)
- Claustrophobic patients.
- Patients who are not willing to participate in the study.

Methodology

Total of 50 patients were included as per the eligibility criteria.

The patients advised intracranial vascular study for suspicion of involvement of intracranial venous system were subjected to MRI of brain with Venography. 3.0 Tesla Whole Body MR Imager Philips MR Systems “Achieva” 3.0 Tesla (Release 2.6.3.5) machine was used for the study. Multi-sequential study in coronal, sagittal and axial sections were taken.

These patients underwent MRV which included use of method/ sequence -2D TOF. This study did not have gold standard to be compared with, which is Digital subtraction Angiography (DSA). In house scans were done on a 3.0 Tesla magnet involving above mentioned sequences and intra-cranial venous structures were studied after standard reconstructions were prepared using Maximum Intensity Projection (MIP) and 180 degrees rotational reconstructions in coronal and axial planes with angle between images 10 degree.

In our study slice thickness for 2D TOF method was 3 mm with distant factor 33%. 2D TOF technique was optimized by choosing a sagittal slice orientation tilted slightly towards coronal and axial directions. Examination time for 2D TOF in our study was 7 minutes 20 seconds. Usually, it is desirable to set the slice thickness as small as possible, typically on the order of 1.0 to 1.5 mm to overcome limitation of 2D TOF method but that would have increased the time

of scan to 10 minutes and therefore was not adopted in this study.

The appearance of various intra-cranial venous structures was assessed in context of their signal intensity, uniformity and extent of dimension of the

structures visible on three different Magnetic Resonance Venography (MRV) methods. Accordingly, values were assigned to each of them on different methods.

TABLE These values ranged from 0-2 and +/- wherein they meant as follows:

0 - When structure was almost unnoticeable or very faintly visible without completeness (hypoplastic)
1 - When structure is visible to some extent or visible completely but narrowed inhomogenously or showing visible flow defects especially in case of sinuses. (partial thrombosis)
2 - When structure is apparently visible without noticeable flow defects or incompleteness. (Complete thrombosis)
P Present in stated case
A Absent in stated case

The structures considered for the study include intra-cranial venous structures which are part of superficial, deep venous systems and dural venous sinuses.

Structures forming deep venous system, included in study, are bilateral Internal Cerebral Veins (ICVs), bilateral Basal veins of Rosenthal (BVRs), bilateral Thalamostriate veins (TSVs), Vein of Galen (VG), Straight Sinus (SS), and Inferior Sagittal Sinus (ISS). Structures from superficial venous system included in study are bilateral veins of Trolard (VTs), veins of Labbe (VLs).

Among dural sinuses Superior Sagittal Sinus (SSS), bilateral Lateral Sinuses (LS), bilateral Sigmoid Sinuses (SGS), Torcular Herophili (TH) were included.

Posterior fossa veins and cavernous sinus were not considered for study as they are difficult to visualize with TOF, PC methods while with CE-MR it is possible to visualize cavernous sinus.

Sequences used in the study with its utility description-

T1WI, T2WI, FLAIR, T2*WI MRV, GRE - Hemo, DWI and ADC are used in diagnosis of sinus thrombosis and the parenchymal changes. 2D TOF MRA technique is used for venogram of cerebral sinuses. The thrombus within the sinus can be imaged with T1 and T2 weighted images or with MRV. In T1 and T2 weighted images the normal venous sinus shows flow void due to moving blood. In thrombosed sinuses the flow void is absent with varying signal depending on the age of thrombus and the sequences used. Absent signal with frayed appearance is a feature of thrombosis. Hypoplastic venous sinus, in plane effect, slow flow is some artefactual conditions for false positive finding. The parenchymal edema appears hyperintense in T2WI and FLAIR images. Venous infarcts appear hyperintense in T2 WI and FLAIR images. It is differentiated from edema by DWI which shows hyperintense regions. Hemorrhage can be intra-parenchymal or in subarachnoid space. Intra-parenchymal hemorrhage appearance in T1 and T2 images vary with the stage of hemoglobin breakdown. FLAIR sequence is highly sensitive for subarachnoid hemorrhage.

Results and Observations

Results on the Basis of the study Performed

This study includes 50 patients with age range from 15 years to 70 years old and mean age of 34.70 years. Sixteen patients (32%) were female and thirty four patients (68%) were male. The most common and earliest clinical presentation in this study was headache followed by motor deficit, seizures, papilledema, visual disturbances, cranial nerve palsy, tinnitus, altered mental status, aphasia, orbital pain, nausea, vomiting, chemosis and proptosis and neck pain/rigidity.

Among the predisposing factors for CVT were post-partum complications, followed by dehydration, trauma and post-surgery complications; however, there was no obvious predisposing factor in few patients. The most common cause of cerebral venous occlusion in this study was venous sinus thrombosis.

MRI features in this study were observed in the form of parenchymal changes and abnormal signals in thrombosed veins and sinuses in both T1 and T2, in addition to blooming and collaterals formation, however no patient with CVT was reported without any parenchymal changes on MR brain imaging.

These changes were seen in the form of acute hemorrhagic infarction in 22 patients, chronic hemorrhagic infarction in 12 patients, gliotic areas in 3 patients, mass effect in form of midline shift in 12 patients, ischemic changes in 12 patients and edema in 5 patients.

The most commonly seen MRI findings were replacement of the signal void of sinuses or veins by abnormal signal intensity; showing three patterns, the first was hyper intense signal in both T1 and T2 (i.e. late sub-acute stage), hyperintense signal in T1 and iso to hypo intensity in T2 (i.e. early subacute stage) while it was hypo intense signal in both T1 and T2

(i.e. chronic stage). Finally, there was one patient with equivocal signal in both T1 and T2 but was diagnosed by MRV.

The main MRV findings in our study were –

- Non-visualisation of occluded veins or sinuses due to absent signal
- Flow defect
- Presence of collaterals that may form in the dura that surrounds the occluded sinus.

These collaterals were noted in three patients in the study. MRV successfully diagnosed all cases.

The most common non-visualized sinus in the study group was SSS noted in 33%, followed by transverse sinus (30%), sigmoid sinus (22%) and straight sinus (4%) in the patients taken up for the study. 3 patients (6%) demonstrated the thrombosis of confluence of sinuses.

More than one sinus thrombosis or occlusion was found in majority of patients. Both cortical and deep veins could not be visualized in 88% (44 patients from 50). Finally it came out to be as a resultant factor that patients with occluded cerebral sinuses or veins had all / symptomatic neuro-parenchymal changes on MRI brain.

Discussion

Cerebral venous system can be divided into two basic components.

A) Superficial System: The superficial system comprising of sagittal sinuses (superior & inferior sagittal sinuses) and cortical veins draining the superficial surfaces of both cerebral hemispheres.

B) Deep System: The deep system comprising of lateral sinus, straight sinus and sigmoid sinus along with draining deeper cortical veins.

Both the systems are mostly draining themselves into the internal jugular veins.

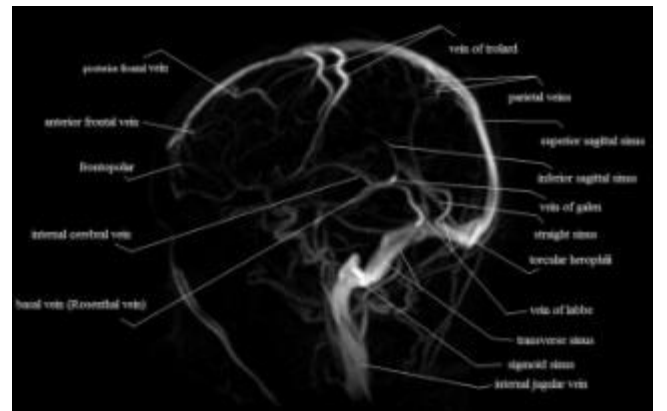
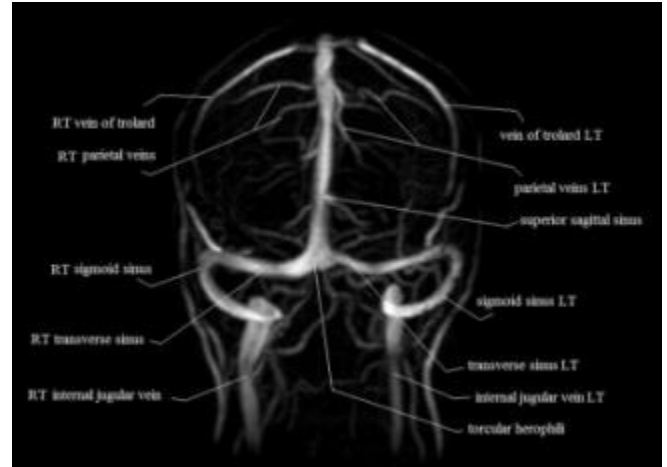
The Superior Sagittal Sinus (SSS) starts at the foramen cecum and runs backwards towards the internal occipital protuberance, where it joins with the straight sinus and lateral sinus to form the Torcular Herophili (TH). Its anterior part is narrow or sometimes absent, replaced by two superior cerebral veins that join behind the coronal suture. The SSS drain major part of the cerebral hemispheres.

The cavernous sinuses drain blood from the orbits, the inferior parts of the frontal and parietal lobe and from the superior and inferior petrosal sinuses. Blood from them flow into the internal jugular veins.

The straight sinus is formed by the union of inferior sagittal sinus and the great vein of Galen (VG).

The inferior sagittal sinus runs in the free edge of falx cerebri and unites with the vein of Galen to form the straight sinus. It runs backwards in the center of the tentorium cerebelli at the attachment of the falx cerebri, emptying into the torcular Herophili at the internal occipital protuberance.

The lateral sinuses extend from torcular Herophili to jugular bulbs and consist of a transverse and sigmoid portion. They receive blood from the cerebellum, the brain stem and posterior parts of hemisphere. They are also joined by diploic veins and small veins of the middle ear. There are numerous LS anatomic variations that may be misinterpreted as sinus occlusion.



Venous sinuses and cerebral veins visualised on MR imaging

The deep cerebral veins are more important than superficial veins from the angiographic point of view. Three veins unite just behind the interventricular foramen of Monro to form the internal cerebral vein including the choroid vein, septal vein and thalamostriate vein. The Choroid vein runs from the choroid plexus of the lateral ventricle. The Septal vein runs from the region of the septum pellucidum in the anterior horn of the lateral ventricle and the thalamostriate vein runs anteriorly in the floor of the lateral ventricle in the thalamostriate groove between the thalamus and lentiform nucleus. The point of union of these veins is called the venous angle. The internal cerebral veins of each side run posteriorly in

the root of the third ventricle and unite beneath the splenium of the corpus callosum to form the great cerebral vein. The internal cerebral veins, which lie within 2 mm of the midline, are the most important deep veins since they can be used to diagnose midline shifts. The great cerebral vein of Galen is a short (1-2 cm long), thick vein that passes postero-superiorly 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. The BVRs begins at the anterior perforated substance by the union of anterior cerebral vein, middle cerebral vein and the striate vein. The basal vein on each side passes around the midbrain to join the great cerebral vein[6].

In summary, blood from the deep white matter of the cerebral hemisphere and from the basal ganglia, is drained by internal cerebral veins. And basal veins of Rosenthal, which join to form the great vein of Galen that drains into the straight sinus. With the exception of wide variations of basal vein, the deep system is rather constant as compared to the superficial venous system. Hence their thrombosis is easy to recognize.

Recognised Causes And Predisposing Factors Of Cerebral Venous Sinus Thrombosis

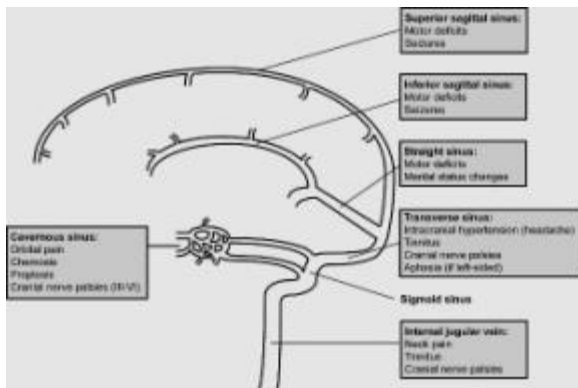
- Infective Causes
 - Local: Penetrating septic head injury, intracranial infection (abscess, empyema, meningitis), regional infection: (Otitis, tonsillitis, sinusitis, stomatitis)
 - General: septicemia, endocarditis, typhoid, tuberculosis.
- Non-Infective Causes

- Local: Head injury, neurosurgery, stroke and hemorrhage, space occupying lesions, idiopathic intracranial hypertension.
- Systemic: Infusions via central venous catheter, surgery with immobilization, Hormonal and endocrine causes, Cardiac disease, Malignancies, Severe dehydration, Inflammatory bowel disease, Connective tissue diseases (Behcet's disease, Sarcoidosis, SLE, Sjogrens), Nephrotic syndrome.
- Drugs: Oral contraceptive pills, Hormonal replacement therapy, L-asparaginase, epsilonaminocaproic acid, ecstasy.
- Blood Dyscrasias: Leukemia, Thrombocythemia, Red blood cell disorders, Sickle cell trait, Paroxysmal nocturnal hemoglobinuria, TTP.
- Coagulopathies: Protein 8, C, antithrombin III deficiency, Factor V Leiden, Antiphospholipids antibody.
- Others: Pregnancy, Thyrotoxicosis, Electrocutation, Idiopathic.

Clinical presentation:

CVST presents with a wide spectrum of symptoms and signs. Headache is the presenting symptom in 70-90% of cases. Focal deficits such as hemiparesis and hemisensory disturbance, seizures, impairment of level of consciousness and papilledema occur in one-third to three-quarters of cases[8]. The onset may be acute, subacute or insidious, most patients presenting with symptoms which have evolved over days or weeks. There are several typical clinical constellations: 18-38% of cases present with a

syndrome resembling benign intracranial hypertension with headache, papilledema and visual disturbances; up to 75% of cases are characterized by a focal neurological deficit and headache; a third group of between 30% and 50% may present with seizures often followed by a Todd's paresis. Rare but classical clinical pictures are that of superior sagittal sinus thrombosis (4%) with bilateral or alternating deficits and/or seizures and cavernous sinus thrombosis (3%) with chemosis, proptosis and painful ophthalmoplegia. An even less frequent presentation is a rapidly progressive illness with deepening coma, headache, nausea and pyramidal signs, due to extensive involvement of the deep cerebral veins.



Major clinical symptoms according to location of cerebral venous thrombosis.

MRI AND MRV:

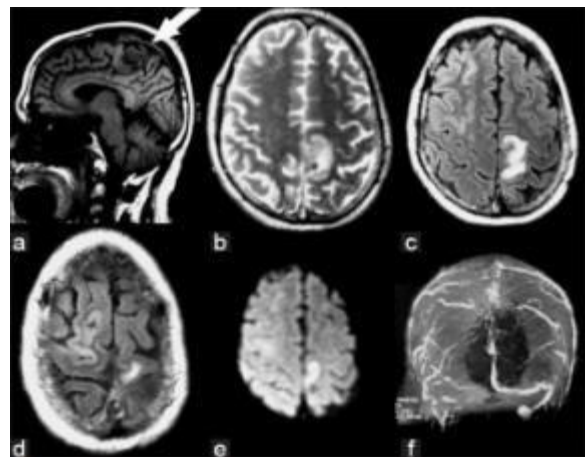
MRI in conjunction with MRV is both sensitive and specific enough to provide the best noninvasive method of diagnosing cerebral venous thrombosis. The diagnosis usually can be made without intravenous contrast although contrast enhancement can aid in confirming the diagnosis. MR Imaging findings are as follows:

- A thrombus can be directly visualized with in a vessel.

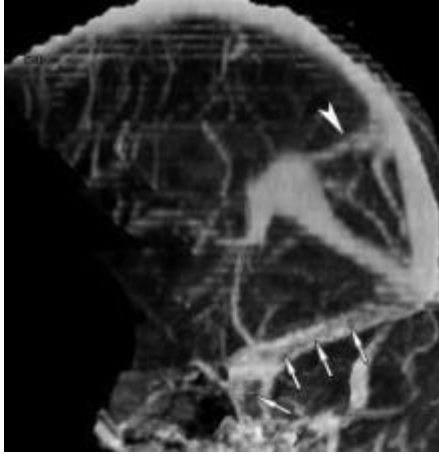
- Secondary venous infarction and foci of hemorrhage can be seen with gradient echo images. Susceptibility induced signal loss from deoxy-hemoglobin provides a basis for detection of even small foci of hemorrhage, which tend to occur in the subcortical white matter, thalami, and basal ganglia.
- Dilated venous collaterals such as transcortical medullary veins provide indirect evidence of venous thrombosis.[9]



Thrombosis in Superior Sagittal Sinus

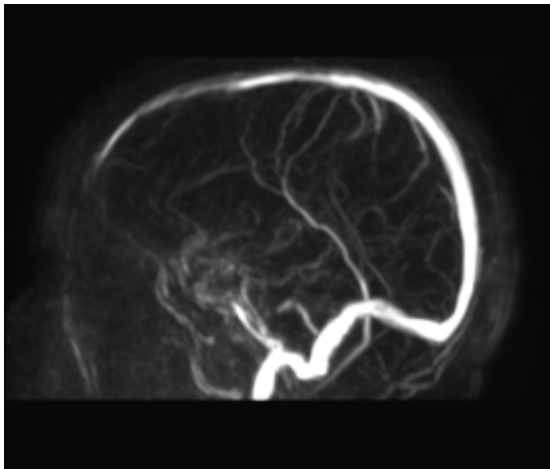


Venous hemorrhagic infarct with Superior Sagittal Sinus thrombosis



Right transverse sinus thrombosis following mastoiditis.

The appearance of intravenous thrombus on conventional MRI depends on the age of the blood clot within the vessels. In acute venous thrombosis, loss of flow void on T1-weighted images occurs along with hypointensity on T2-weighted images, making the determination of sinus occlusion difficult.



Vein of Galen thrombosis

In subacute phase, blood clot can result in loss of normal flow void on T1 weighted images and T1 hyperintensity; conversely, on T2-weighted images blood clot can be of low signal intensity, thus mimicking flowing blood. In this instance, blood is in the intracellular methemoglobin stage. Flow-related

enhancement phenomenon created slow flow can occur in veins and cause T1 hyperintensity.

To circumvent this problem, flow sensitivity imaging techniques can be used (i.e. 2D TOF or Phase contrast MRV) to accurately assess the venous sinuses; 2D TOF MRV pulse sequence is sensitive to slow flow. Maximum signal is produced when blood flows orthogonal to the imaging plane, and since many cerebral veins course in an antero-posterior direction, coronal acquisition is often used with an inferior saturation pulse to eliminate arterial signal.

In MRA, 2D TOF sequence takes less time than PC MRV, however 2D TOF is limited by high signal substances like fat or methemoglobin.

Degree of confidence: Variants of normal anatomy are common, and a hypoplastic sinus or prominent arachnoid granulations may simulate venous sinus thrombosis.[10] With 2D TOF MRV techniques, thrombus in the intracellular or extracellular methemoglobin stage can present with increased signal and falsely simulate blood flow. Phase contrast MRV may avoid this error. False Positive/Negatives: Hypoplasia or severe attenuation of a transverse sinus, which are normal anatomic variants, may simulate venous sinus thrombosis.

In plane flow related signal loss in 2D TOF MRV also can mimic intravenous thrombus. .

This flow related enhancement can be reduced with a “saturation band”. High signal can also result from rephasing of spins. Comparison of scans obtained with and without gradient moment nulling techniques may help to identify the artifact.

Prominent arachnoid granulations may simulate thrombus. A careful review of the MRV images and conventional MRI may lead to correct diagnosis.

Conclusion

CVT is a potentially fatal condition which if recognized and treated appropriately has excellent prognosis. MRI and MRV is the best diagnostic modality for CVT. The combination of hyperintense T1 and T2 signals from the sinus, associated with a

defect seen on the MR venogram, in the appropriate clinical setting are diagnosed of CVT. These changes may be seen with or without parenchymal changes. Caution should be exercised in the interpretation of the MR images to avoid potential pitfalls.

References

1. Heiserman JE, Dean BL, Hodak JA, Flom RA, Bird CR, Drayer BP, et al. Neurologic complications of cerebral angiography. *AJNR Am J Neuroradiology* 1994; 15:1401-7
2. Agid R, Shelef I, Scott JN, Farb RI. Imaging of the intracranial venous system. *Neurologist* 2008; 14: 12-22.
3. Scott JN, Farb RI. Imaging and anatomy of the intracranial venous system. *Neuroimag Clin N Am* 2003; 13: 1-12.
4. Stam J. Thrombosis of the cerebral veins and sinuses. *N Engl J Med* 2005; 352 : 1791-8.
5. Ayanzen RH, Bird CR, Keller PJ, McCully FJ, Theobald MR. Cerebral MR Venography: Normal Anatomy and Potential Diagnostic Pitfalls. *AJNR Am J Neuroradiol* 2000; 21 : 74-78.
6. Higgins JN, Gillard JH, Owler BK, Harkness K, Pickard JD. MR venography in idiopathic intracranial hypertension: unappreciated and misunderstood. *J Neurol Neurosurg Psychiatry* 2004; 75 (4):621-5
7. Liang L, Korogi Y, Sugahara T. Evaluation of the intracranial dural sinuses with a 3D contrast – enhanced MP – RAGE sequence: Prospective comparison with 2D-TOF MR venography and digital subtraction angiography. *AJNR Am*
8. Einhaupl KM, Masuhr F. Cerebral Venous and Sinus thrombosis – an update. *Eur J Neurol* 1994; 1 : 109 – 26.
9. Villringer A, Mehraen S, Einhaupl KM. Pathophysiological aspects of cerebral venous sinus thrombosis. *J Neuroradiol* 1994; 21 : 72-80.
10. Anne G. Osborn. Venous Occlusions In : *Diagnostic Neuroradiology : Stroke*. USA: Harcourt Brace and Company Asia PTE LTD, Mosby – Year Book; 2004 : 385 – 395.