ROLE OF CT VENOGRAPHY AND MR VENOGRAPHY IN CEREBRAL VENOUS THROMBOSIS
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ABSTRACT

INTRODUCTION
CVT often presents with haemorrhagic infarction in areas atypical for arterial vascular distribution. Cerebral haemorrhage or focal oedema due to venous congestion or infarction is often findings at CT that lead to further imaging evaluations. Subcortical haemorrhages, while nonspecific has been reported as a common finding in CVT.

AIMS AND OBJECTIVES
To evaluate the imaging characteristics of cerebral venous thrombosis on CT and MR imaging, to appreciate the diagnostic pitfalls of MR venography in the diagnosis of cerebral venous thrombosis and to compare CT Venography and MR Venography in the diagnosis of cerebral venous thrombosis.

MATERIAL AND METHODS
This prospective study was done at Department of Radio-Diagnosis and Modern Imaging, Jaipur from September 2005 to November 2007. The study comprised of 30 patients that presented to the MR imaging with suspected untreated cortical venous thrombosis for obtaining MRV. CTV was also done in cases of dural sinus thrombosis.

RESULTS
The age range of patients in the study was between 19 and 58 years. The commonest age range was 20-25 Years (46%). Number of female patients was higher (83.3%). Most common risk factor in the study group was postpartum/puerperal status, followed by infection, and others. The clinical presentation in present study was acute in majority of patients. Most common sinus to be involved is superior sagittal sinus (66.6%) followed by transverse sinuses (61.1%) and sigmoid sinus (55.5%).

CONCLUSION
CT Venography is an effective, alternative imaging modality that overcomes the technical limitations of MRV and should be used in cases where technical limitations impede confident diagnosis of CVST on MRV.

KEYWORDS
Cerebral Venous Thrombosis, CT Venography, MR Venography.


INTRODUCTION: Cerebral venous sinus thrombosis (CVST) is an uncommon condition, which over the past 5 to 10 years has been diagnosed more frequently due to greater awareness and the availability of better non-invasive diagnostic techniques. The main cerebral venous sinuses affected by CVST are the superior sagittal sinus (72%) and the lateral sinuses (70%). In about one-third of cases, more than one sinus is affected. In a further 30-40%, both sinuses and cerebral or cerebellar veins are involved. Pathophysiologically, there are important differences between arterial and venous thrombosis. CVST has been described as a continuing process in which the balance of prothrombotic and thrombolytic processes is disturbed, leading to progression of the venous thrombus with time. This slow growth of the thrombus and the good collateralisation of the venous vessels probably explain the usually gradual onset of symptoms, frequently over weeks and months. Sudden onset; however, has been described. Recovery appears to be unrelated to the duration of symptoms and signs. Haemorrhagic infarction occurs in approximately 10-50% of cases, principally affecting the cortex and adjacent white matter. This is thought to be primarily due to elevated venous and capillary pressure caused by the persistence of thrombosis.

AIMS AND OBJECTIVES:
1. To evaluate the imaging characteristics of cerebral venous thrombosis on CT and MR imaging.
2. To appreciate the diagnostic pitfalls of MR venography in the diagnosis of cerebral venous thrombosis.

MATERIAL AND METHODS:
Selection of Cases: This comparative study was done at Department of Radiodiagnosis and Modern Imaging, Jaipur from the pool of patients that presented to this department. The study comprises of approximately 30 patients that presented to the MR imaging with suspected untreated cortical venous thrombosis for obtaining MRV, which is the current gold standard technique for diagnosis of cerebral venous thrombosis.

CT Protocol: All CT examinations were performed using Light-Speed Advantage Helical CT (16 multislice scanners with Advantage Windows workstations (General Electric Medical Systems, USA). Scan protocol for CT venography consists of a 10-mm-collimated helical scan in the axial plane using a pitch of 0.938:1 (table speed, 2.0 mm/sec). The data were acquired by scanning caudally from the skull vertex to the skull base with the scanner angled parallel to canthomeatal line posterior margin of the foramen magnum. Scan parameters included 120 kVp, a tube current of 350 mA, and a 20- to 22-cm display field of view. The source images were displayed with an approximate window setting of 550 H and a level of approximately 250 H to clearly visualise the dural venous sinuses as separate from the adjacent bone.

Nonionic contrast material (100 mL Ultravist 370 mg at a rate of 3.5 mL per second) was administered into a peripheral IV catheter, and a 40-sec prescan delay was used. The CT 3D reconstructions used a subtraction technique that isolated the brain from the surrounding calvarium and subcutaneous tissues. First, a 3D model of the entire scan data (primary model) is created. Next, a bone model is built from a duplicate of the primary model, and this bone model is then subtracted from the primary model, creating a first-phase vascular model. At this point, the vascular model is still obscured by overlying fragments of bone. The bone model can be dilated and then subtracted again from the vascular model, which yields a secondary vascular model. The venous structures are now more clearly visualised on the maximum-intensity-projection (MIP) image when overlying bony fragments have been removed. This dilation and subtraction technique may be repealed until the venous structures are clearly depicted. In most cases, diagnostic venograms were obtained after only one or two subtraction steps.

MRI Protocol: MR examinations will be performed with 1.5-T Signa Excite MR imaging system (General Electric Medical Systems) in all 30 patients using standard head coil with two-dimensional (2D) TOF MR angiography technique. Parameters used for the 2D TOF MR venography were a TE of 15 msec, TR of 25 msec, 60-degree flip angle, and 1.5-mm slice thickness with spacing of zero, one excitation, 256 x 192 matrix, and 24 cm field of view with frequency encoding in a superoinferior direction.

The imaging volume was oriented in the sagittal plane for evaluation of the superior sagittal sinus, straight sinus, and deep cerebral veins and was oriented in the axial plane for evaluation of the transverse and sigmoid sinuses. The 2D TOF scan data will be transferred to the GE Advantage Windows workstation for post processing to create a projection venogram with MIP algorithm and for segmentation of the scan data to create a midline sagittal slab-MIP.

Display Algorithms: Projection venograms of both CT and MR imaging were displayed using the MIP algorithm. MIP algorithm projects intensity on the viewing screen that is the brightest intensity in the 3D model volume along a ray perpendicular to the viewing screen. This display technique enables one to visualise the high-density or high-intensity vessels through the low-density or low-intensity brain parenchyma. Segmented or cutaway views can be used with the MIP algorithm to eliminate overlapping vessels.

MR and CT Correlation: The projection venograms were rotated about the superior-inferior axis at 15-degree increments, which provided anteroposterior, lateral, and multiple oblique views for interpretation.

Source images from the CT venograms and MR venograms will be included for review as well. The images of each case were archived on compact discs from the workstation after post processing in DICOM format with in-built CD viewer provided by GE Medical Systems, USA.

RESULTS:

<table>
<thead>
<tr>
<th>Age</th>
<th>Male</th>
<th>Female</th>
<th>Total</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;20</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>3.33</td>
</tr>
<tr>
<td>20-25</td>
<td>1</td>
<td>13</td>
<td>14</td>
<td>46.66</td>
</tr>
<tr>
<td>26-30</td>
<td>1</td>
<td>5</td>
<td>6</td>
<td>20</td>
</tr>
<tr>
<td>31-35</td>
<td>1</td>
<td>4</td>
<td>5</td>
<td>16.66</td>
</tr>
<tr>
<td>36-40</td>
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<td>2</td>
<td>2</td>
<td>6.66</td>
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<tr>
<td>&gt;40</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>6.66</td>
</tr>
</tbody>
</table>

Table 1: Age wise distribution of Cases (Majority of cases belonged to the age group of 20-25 years)

<table>
<thead>
<tr>
<th>Cases</th>
<th>Number</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Males</td>
<td>5</td>
<td>16.66</td>
</tr>
<tr>
<td>Females</td>
<td>25</td>
<td>83.33</td>
</tr>
</tbody>
</table>

Table 2: Sex wise distribution of Cases (Eighty three percentages of cases are females)

<table>
<thead>
<tr>
<th>Imaging Findings</th>
<th>Number of cases</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Haemorrhagic infarcts</td>
<td>8</td>
<td>44.44</td>
</tr>
<tr>
<td>Thalamic inv</td>
<td>2</td>
<td>11.11</td>
</tr>
<tr>
<td>No abnormality</td>
<td>8</td>
<td>44.44</td>
</tr>
</tbody>
</table>

Table 3: Distribution of Imaging Findings on MRI in Patients with CVT
Patients with a range of 15-70 years were studied. The commonest age range was 20-25 Years. The number of females was significantly more than males. Out of thirty patients, 5 were males and 25 were females. 18 patients showed evidence of sinus thrombosis. In the international study on CVST, the female to male ratio was 2.9 and the mean age was 39 years. (Table 1 and 2)

Most common risk factor in the study group was postpartum state, sepsis and others. In some cases, idiopathic cause was found. In the international study on CVST, the predisposing factors found were- OCPS (46%), pregnancy/ puerperium (17%), ENT infections (8%), CNS infections (5%), other infections (4%), CNS disorders (5%), vasculitis/APL (8%) and other systemic diseases (14%).

In the present study, CVST was observed in 18 cases, predominantly in postpartum patients, particularly young patients in the age group of 20-30 years. 8 patients had haemorrhagic infarct and 2 patients had bilateral thalamic hyperintensities. No parenchymal abnormality was detected in 8 patients (Table 3). The findings resemble the observations reported by Ameri Bousser et al (2). In their study, 61% of women with CVT were aged 20-35 years. A latent period of five to seven days was observed in these patients. The most frequent alternate diagnosis was either postpartum encephalopathy or psychosis.

Infectious cause was noted in only one case, of ENT origin. A case of internal jugular vein thrombosis secondary to schwannoma was found. Postpartum ischaemic infarct in one case. Forty four percent of patients with CVT had haemorrhagic infarcts. Eleven percent of them had deep venous involvement with thalamic involvement.

**Comparative Evaluation of CTV and MRV:** In the current study, on CT, infarctions in a non-arterial distribution in the white matter and/or cortical white matter junction, often associated with haemorrhage suggested the possible diagnosis of CVST. Findings correlate with those of Walter M et al. He concluded that the diagnosis should be strongly suspected in a young female patient if the lesion is within basal ganglia or thalamus and especially if it is bilateral. In the present study, the CT scan findings were haemorrhagic infarcts in forty four percent of patients and hyperdensity of veins in two patients (Table 4 and 5).

In the present study, the MR scan findings were haemorrhagic infarcts in forty four percent of patients. Comparative evaluation of CTV and MRV was done in all studied patients. Empty delta sign is the best and most frequently noted CT sign of dural sinus thrombosis present in approximately 37% of published patients, as of Bousser and Russell's report in 1997. Hyperintense signals were noted in dural sinus thrombosis on MR image and signal intensity varies with the age of the thrombus. The involvement of dural sinuses was similar in both CTV and MRV in all the 18 cases, except for superficial cortical veins which was better depicted on CTV (Table 4 and 5).
DISCUSSION: Cerebral venous thrombosis remains a diagnostic challenge and a potentially disabling or lethal disease. It can affect all age groups but predominantly the postpartum/puerperal patients are at increased risk. The range of clinical spectrum and non-specific laboratory results mean that imaging plays a vital role in the diagnosis of CVST.

CVT often presents with haemorrhagic infarction in areas atypical for arterial vascular distribution. Cerebral haemorrhage or focal oedema due to venous congestion or infarction is often findings at CT that lead to further imaging evaluations. Subcortical haemorrhages, while nonspecific has been reported as a common finding in CVT. Both CTV and MRV are good tools for identifying occluded sinus. MRV has its own limitations with respect to flow dynamics and the technique used, with slow flow often masquerading as thrombus on 2DTOF MRV. CTV significantly scores over MR with respect to flow related artefacts; however, CTV can be normal, requires diligent post processing of source images. CT can be normal in 10-20% of cases. CT scan, both NECT and CECT should be the first investigation due to its widespread availability and lesser cost. The main drawback of CT scan is ionising radiation and use of contrast for visualisation of dural sinuses.

Alternative cerebral parenchymal abnormalities in patients suspected of having CVST are better noticed on MRI compared to CT scan. Prognosis of patients with CVST is excellent provided early diagnosis, effective anticoagulation and proper followup is done. In these cases, imaging plays an effective role. Recent technical advances in the imaging of CVST include use of contrast enhanced MR (CE-MR) and various new pulse sequences that overcome the flow-related limitations of 2D TOF MRV.
Susceptibility weighted imaging (SWI) is capable of detecting the thrombus, oedema and even haemorrhage after venous infarction because it combines the properties of T2 relaxation and susceptibility differences between tissues. It has an important role in both acute as well as chronic venous thrombosis.

Robert R Ozsvath(1) et al concluded in his study that cerebral CT venography is superior to MR venography in the identification of cerebral veins and dural venous sinuses and is at least equivalent in the diagnosis of dural sinus thrombosis. CT venography is a viable alternative to MRV in the examination of patients with suspected dural sinus thrombosis. Casey(2) et al concluded in his study that CT venography yields detailed images of the intracranial venous circulation with consistent high quality. It is a rapid, useful method for diagnosis of dural sinus thrombosis and for preoperative imaging of venous structures in patients with neoplasm.

E. Widjaja and P.D. Griffiths(3) et al reviewed the cerebral venous anatomy in children by using MR venography. It is important to recognise the variations of venous anatomy and not mistake them for pathologic abnormalities. They also reviewed the literature on the development of the venous structure. This provides the background for further MR venography study of the venous system in malformations of the brain. C Virponse et al(4) determined the frequency of occurrence of empty delta sign and its prognostic significance by reviewing 76 reported patients of SST and SST related intracranial hypertension. They concluded that empty delta sign is the most frequent and the best CT sign of DST, present in 35% of the patients. Ahmed Idbaih(5) et al concluded in their study that T2SEW imaging appears to be of additional diagnostic value in CVT. The T2SEW sequence may be particularly useful during the acute phase of CVT when the sensitivity of the other sequences is incomplete and for the diagnosis of isolated cortical venous thrombosis.

Surendrababu Narayanam(6) et al concluded in their study that MR angiography done at low field strengths is also a reliable method, for assessing cerebral venous sinuses. Awareness of the normal anatomical variations of venous sinuses and apparent MR angiographic flow gaps prevent misdiagnosis of cerebral venous sinus thrombosis. Kumar Anil(7) et al conclude in their study that venous sinus thrombosis presents as loss of normal flow void on routine sequences, especially on FSE T2W and FLAIR images we may suspect venous sinus thrombosis on routine MRI sequences, and the finding can be confirmed by MR venography so that further management can be planned promptly and patient can be saved from its complications. This is especially important in subacute cases in which the balance of prothrombotic and thrombolytic processes is disturbed, the thrombus is in gradual growing process and there is no brain parenchymal damage. Hence, they strongly insist and reiterate that absence of normal flow void within the dural sinus should be taken into account and further evaluated by MR venography to confirm the finding. K Y Lau et al(8) in their study conclude that, DST should be suspected in patients with known risk factors who present with neurologic symptoms. The presence of subcortical haemorrhage or focal cerebral oedema on CT or MRI in patients with a nonspecific clinical presentation should alert the radiologist to the possibility of DST. MRI should be performed promptly if CT has been the initial investigation and is not diagnostic. MRV is helpful, but may not be needed to reach the diagnosis of DST in acute cases.

Christine heller et al(9) concludes in their study that CVT in children is a multifactorial disease and in majority of cases results from a combination of prothrombotic risk factors and underlying clinical condition. Buonanno FS(10) et al studied 11 patients with angiographically and/or pathologically proven cerebral sinovenous occlusions by CT. CT findings included visualisation of thrombosed vein or sinus, multiple focal bilateral parasagittal haemorrhages, intense tentorial enhancement, and intense gyral enhancement indistinguishable from infarct, solitary intracerebral haematoma, small ventricles and normal scan. They suggested that, in most instances, NECT scan in patients with suspected CVT serves to mainly depict secondary changes in brain parenchyma such as venous infarcts and oedema. It also excludes other abnormalities in the initial workup.

Vogl TJ(11) et al performed a prospective study, the results of which indicated that arterial and venous MR is of great value in paediatric neurovascular problems. Its noninvasive nature makes it well suited for routine use in children. Ayanzen et al(12) also evaluated the use of MR venography in the depiction of the normal intracranial venous anatomy and its variants, assessed its potential pitfalls in the diagnosis of dural sinus thrombosis. They also made a comparative evaluation with catheter angiography. In a systematic review of 100 patients, they observed transverse sinus flow gaps in as many as 31 patients with normal MR imaging findings; these gaps should not be mistaken for thrombosis.

D. W. Chakrees et al(13) demonstrated normal venous anatomy of brain with gadopentate dimeglumine in 3D contrast enhanced MR angiography. Enhancement with this agent affords rapid scanning and excellent visualisation of the pertinent venous anatomy. H P Mattie et al(14) described a two dimensional TOF technique MRA to create projection venograms of the head. MRV proved helpful in identifying thrombosis or patency of cerebral veins and sinuses and showed collateral venous drainage from AV malformations. There was good correlation between conventional DSA and MRV. They concluded that MRV is reliable for showing the cerebral venous system.

WT Yuh(15) et al studied the MR patterns of venous sinus occlusive disease and related them to underlying pathophysiology by comparing the appearance and pathophysiological features of venous occlusive disease with that of arterial ischaemia. Oppenheim et al(16) reported four patients with subarachnoid haemorrhage as the initial presentation of DST. In all patients, the SAH involved convexity sulci and spared the basal cisterns. DSA showed occlusion of intracranial venous sinuses, but did not reveal
any cause for SAH. This highlights the fact that SAH involving convexity sulci may harbour an occult CVT.

Krishnan et al\(^\text{17}\) reported CVST and DST in severe falciparum malaria cases. A hypercoagulable state resulting from underlying disease may be responsible for this rare and potentially fatal complication. The diagnosis should be suspected in these patients with FND and appropriate imaging should be done. Dormant et al\(^\text{18}\) observed enhancement of thrombi in all their patients with chronic thrombi and they attributed this enhancement to thrombus organisation. Gradient imperfections, eddy currents and aliasing artefacts that occur when flow velocities exceed the expected values limit the usefulness of phase contrast angiography.

JS Tsurda et al\(^\text{19}\) evaluated dural sinus occlusion with phase sensitive gradient-echo MR imaging. TOF angiography overestimated the extent of thrombus caused by spin saturation. Keiper et al\(^\text{20}\) identified subcortical haemorrhage (SCH) as an indicator of radiographically occult CVT on CT. SCH can be seen in association with acute CVT and can be the sole abnormality on CT. SCH as an isolated finding on CT suggests the possibility of CVT warranting further investigation with MRI.

Ogami R et al\(^\text{21}\) diagnosed acute phase of venous infarction by diffusion weighted imaging. Farb et al\(^\text{22}\) used gadolinium enhanced three dimensional automatically triggered elliptic centric-ordered MRV for imaging of intracranial venous system and proved it to be superior to TOF technique.

SWI is sensitive in detecting intravenous deoxygenated blood as well as extravascular blood products. It was originally referred to as high-resolution blood oxygen level-dependent (BOLD) venography.\(^\text{23,24}\) Because of its sensitivity to susceptibility effects, SWI is of additional diagnostic value for detection of acute thrombus in CVST in conjunction with conventional MRI sequences and MR Venography, particularly in the acute phase of thrombosis and in cortical cerebral venous sinus thrombosis.\(^\text{5}\)

**CONCLUSION:**

- CT Venography is an effective, alternative imaging modality that overcomes the technical limitations of MRV and should be used in cases where technical limitations impede confident diagnosis of CVST on MRV.
- Current gold standard in the diagnosis of this entity is MRI combined with MRV. Though it has some limitations with respect to widespread availability, cost, general contraindications to scanning, technical limitations, in majority of cases a diagnosis can be made. Equivocal cases on MRV have to undergo DSA for confirmation of the diagnosis.

**REFERENCES**