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Cerebral venous sinus thrombosis: Comparison of multidetector computed tomography venogram (MDCTV) and magnetic resonance venography (MRV) of various field strengths

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Abstract

Objectives: To investigate the accuracy of multidetector computed tomography venography (MDCTV) and magnetic resonance venography (MRV) of differing field strength in diagnosing cerebral venous sinus thrombosis (CVST). To assess the visualization rate of the cerebral veins and dural sinuses between these imaging modalities. *Methods*: A retrospective review of 27 patients with clinical suspicion of CVST who underwent both MDCTV and corresponding MRI/MRV brain scans at 0.35T, 1.5T or 3.0T field-strength were performed. Results were compared with the definitive final diagnosis. In the non-thrombotic group of patients, a descriptive study of the anatomical visualization of cerebral veins and dural sinuses was also undertaken. *Results*: Ten of the 27 patients had a final diagnosis of CVST. The Neuroradiologists' consensus reading identified these 10 cases of CVST in both the MDCTV and MRV scans with a sensitivity rate of 100%. There was one false positive in MDCTV and three false-positives in the MRV group (1.5T) with positive predictive values of 90.9% and 76.9%, respectively. MDCTV and MRV demonstrated a specificity of 94.1% and 82.4%, respectively in diagnosing CVST. No false negative images were seen demonstrating a negative predictive value of 100% in both modalities. There was no statistical difference in the anatomical visualization rate of the cerebral veins or the dural sinuses among the various strengths of MRI. However, statistically significant ($p<0.05$) fewer visualised vessels in MRV compared to MDCTV, for the SSS, ISS, straight sinus, ICV and VOG.
Conclusion: MDCTV is equal to MRV of various strength in its sensitivity for CVST diagnosis. MDCTV also provides better anatomical visualization of the dural sinuses and cerebral veins.

INTRODUCTION

Cerebral venous sinus thrombosis (CVST) often presents with non-specific symptoms, hence, the diagnosis can be elusive. The main presenting symptom in 70 to 90% of cases is headache, which is often misdiagnosed as migraine or tension headaches.[1] Propagation of thrombus would cause venous infarcts resulting in more specific focal neurological deficits, such as hemiparesis, paraesthesia, seizures or altered level of consciousness (in 33-66% of patients). Generally, by the time diagnosis is made, an interval of 7 days has elapsed from the onset of symptoms.[1]

The gold standard for diagnosing dural sinus thrombosis has been cerebral angiogram.[1-3] The commonly accepted method, possibly considered the gold standard for non-invasive techniques in diagnosing dural venous thrombosis is magnetic resonance venography (MRV).[1,2,4,5] However, the newer MDCT scans, which are capable of performing helical scans at high speed coinciding with peak venous enhancement, is also able to provide good diagnostic image quality. Thus, the idea of using MDCTV to rule out dural venous thrombosis is compelling as it is fast and more readily available. Moreover, MRV is prone to motion artefact due to its long acquisition time and susceptible to flow artefact in the 2D-Time-Of-Flight (TOF) sequences.

Another imaging technique of MRV, which is the 2D-phase contrast sequence, displays limited

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view as it only acquires a single midline image of sagittal plane as compared to the full volume acquisition in MDCTV. To our knowledge there has been no study to compare the sensitivity and specificity in diagnosing CVST between 16-sliced MDCTV against various field-strengths of 0.35T, 1.5T and 3.0T MRV as undertaken in the present investigation This study also includes a descriptive component to compare the visualisation rate of dural venous sinus anatomy between these modalities (Figures 1 and 2).

METHODS

This is a cross sectional retrospective study of clinically suspected CVST patients who presented to the Biomedical Imaging Department of University Malaya Medical Centre from August 2007 to July 2009. Twenty-seven patients were included. Approval by the institutional review board committee and written informed consent were obtained from all patients. MRI/MRV and MDCTV imaging of the brain were performed within 48 hours of either examination. The order of the imaging modalities was randomly chosen. Eighteen patients had MDCTV as the initial scans, followed by MRI/ MRV for comparison. The other nine patients had MRI/MRV investigations, followed by MDCTV. Seventeen of the patients had undergone scans in the 1.5T (Magnetom Vision Siemens) and another four patients were investigated in the 0.35T Siemens Magnetom C!. Five patients were scanned in the 1.5T machine (MR Signa EXCITE – GE) and the last four patients were investigated using the 3.0T MRI (MR Signa HDx – GE). The CT scanner utilized in this study comprised of two different models of similar capability. Twelve patients had undergone scanning in the GE® (General Electric) Lightspeed-16 and another 15 patients were investigated with Siemens Somatom Sensation-16, where both of these CT scanners were 16-row multidetector CT.

Computed tomography venography (CTV)

Cross-sectional images of the brain were obtained caudo-cranially from the base of skull to vertex using Helical CT acquisition performed at a delayed 90sec interval from the time of injection of 80mL 300mg/I contrast media, followed by 20 mls of 0.5% normal saline push at the rate of

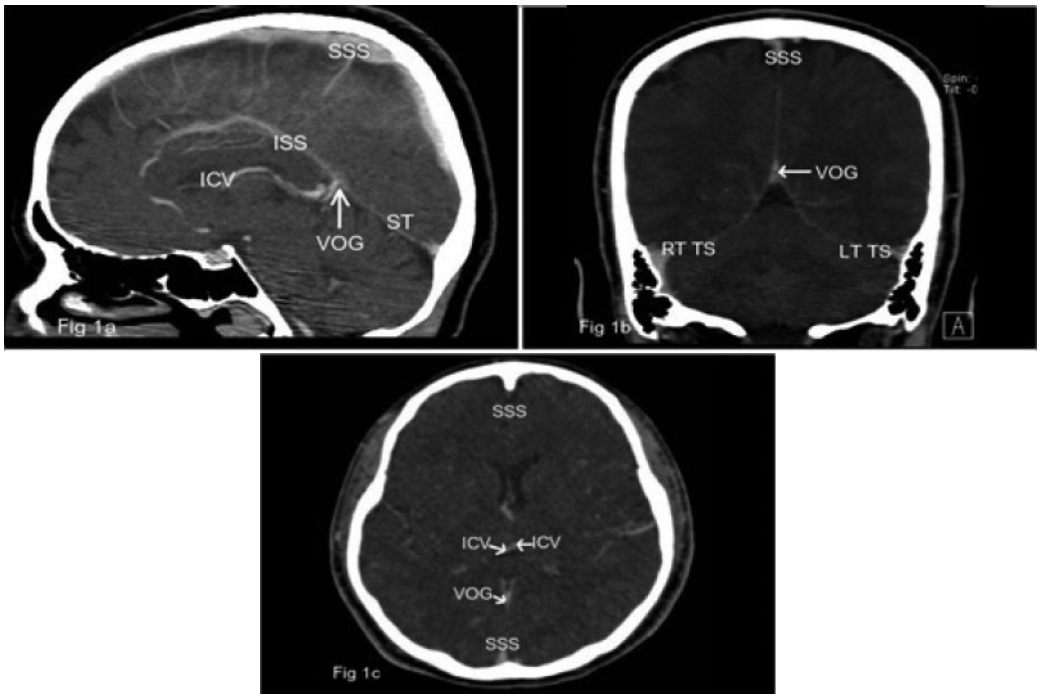

Figure 1. Contrast enhanced CT venogram (MDCTV) projected in multiplanar reformatted (MPR) images of the sagittal view (1a); coronal view (1b) and axial view (1c) showing normal anatomy of the cerebral veins and dural sinuses. SSS, superior sagittal sinus; ISS, inferior sagittal sinus; ICV, internal cerebral vein; VOG, vein of Galen; ST, straight sinus; RT, right, LT, left

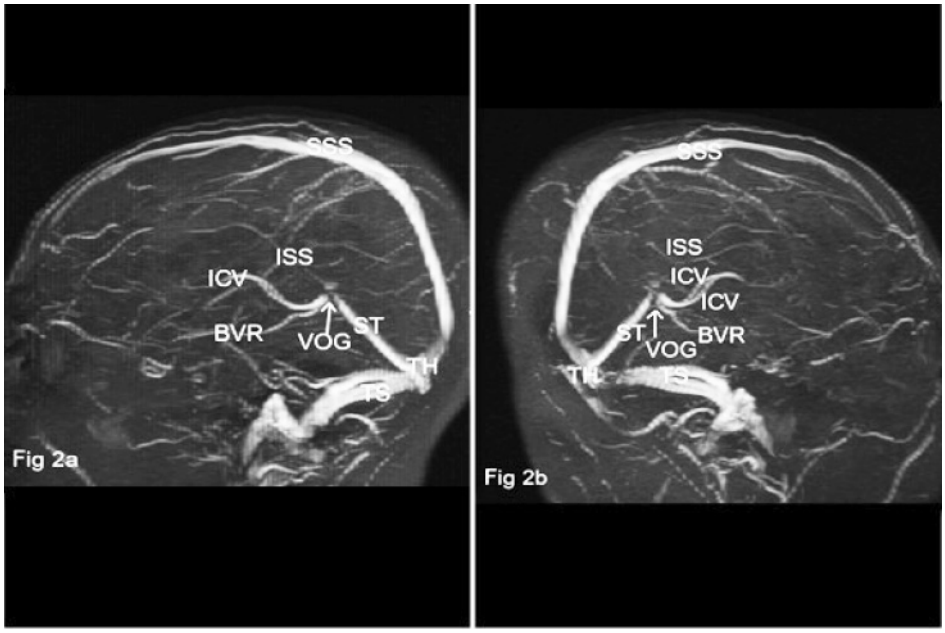

Figure 2. Non-contrast enhanced 2D-TOF magnetic resonance venogram (MRV) projection in lateral view (2a) and oblique view (2b) showing normal anatomical structures of the cerebral veins and dural sinuses. SSS, superior sagittal sinus; ISS, inferior sagittal sinus; ICV, internal cerebral vein; VOG, vein of Galen; ST, straight sinus; TS, transverse sinus; TH, Torcula Heterophili.

4mL/sec via an 18G intravenous catheter set at the right antecubital fossa. The scan parameters used were 120kV and collimation of 16 x 0.625mm for GE or 16 x 0.75mm for Siemens machines.

Magnetic resonance imaging (MRI) and MR venography (MRV)

Four MR machines of various field strengths were used in this study. Continuing expansion of the authors's institutional healthcare services during data collection had included decommissioning of one old MRI machine and commissioning of three new units in stages. The machines and their respective scanning parameters which were utilised at the time of study were (i) Magnetom Vision 1.5T MR imaging unit (Siemens, Erlangen, Germany); T1 Flash 2D TOF Coronal - TR/TE 30/9, 70° flip angle, slice thickness 5mm and 128 x 256 matrix; Phase contrast 2D - velocity encoding strength 15cm/sec, TR/TE 93/11, slab thickness 50mm, 20° flip angle and 128 x 256 matrix; (ii) Magnetom C! 0.35T imaging unit (Siemens, Switzerland) -T1 Flash 2D TOF Coronal - TR/TE 39/10, 70° flip angle, slice thickness 3mm and 156 x 256 matrix; (iii) MR Signa EXCITE 1.5 T imaging unit (GE, Milwaukee) - T1 Flash 2D TOF Coronal - TR/TE 24/5, 60° flip angle, slice thickness 1.4mm and 160 x 256 matrix; Phase contrast 2D - velocity encoding strength 15cm/sec, TR/TE 28/8, slab thickness 60mm, 20° flip angle and 160 x 256 matrix and (iv) MR Signa HDx 3.0T imaging unit (GE, Milwaukee) -T1 Flash 2D TOF Coronal - TR/TE 21/7, 70° flip angle, slice thickness 2mm and 320 x 192 matrix; Phase contrast 2D - velocity encoding strength 15cm/sec, TR/TE 14/6, slab thickness 100mm, 20° flip angle and 256 x 192 matrix.

Image interpretation

The CT and MR images were reviewed using a General Electric Workstation (GE Medical Systems, Milwaukee) with Advantage Windows version 4.2 software. CTV and MRV images of each patient were reviewed separately and interpreted by two Neuroradiologists by consensus method. The clarity of the anatomical structures of the cerebral veins and dural venous sinuses was assessed and grading scores given on a 3-point scale: 0 – Structure is poorly visualized or not visualised; 1 – Structure shows presence of flow void; 2 – Structure is fully opacified.

If a cerebral vein or dural venous sinus was not visualized or poorly visualized, suspicion of sinus thrombosis was considered. A 3-point grading score was again given to assess the confidence level of diagnosing sinus thrombosis in these

individual structures: 0 – No sinus thrombosis; 1 – If presence of thrombosis is indeterminate; 2 – If there was presence of sinus thrombosis.

At the end of analyzing each CT or MR images, the Neuroradiologists will conclude the presence of any sinus thrombosis according to 5-point grading score which correlates to the degree of confidence in diagnosis: 1 – No sinus thrombosis; 2 – Likely no sinus thrombosis. Flow void was due to arachnoid granulation or flow artefacts; 3 – Presence of sinus thrombosis is indeterminate and required further investigation with other imaging modality; 4 – Highly suspicious of sinus thrombosis; 5 – Presence of sinus thrombosis.

On CTV, venous sinus thrombosis was diagnosed by the presence of intraluminal thrombus that appeared as filling defects (Figure 3a) or the triangular Delta sign (Figure 3b). On brain MRI the occurrence of thrombosis is manifested as abnormal hyperintense signal within the normally hypointense venous sinus on sagittal T1-weighted or T2-weighted images (Figure 3c). On 2D-TOF MRV sequence, the thrombus will be projected as flow void within the sinus (Figure 3d). Figure 4 shows a case of sagittal sinus thrombosis depicted as flow void abnormality on the 2D TOF MRV and filling defects on CTV as well as abnormality on the venous phase of cerebral angiography.

In this study**,** findings from MDCTV and MRV were compared with the final-diagnosis, which served as the definite reference gold standard. This final-diagnosis was derived from the clinical symptoms, patient outcome and consensus from multidisciplinary neuroradiology meeting and findings from follow-up CT and MRI imaging, when available.

RESULTS

A total of 27 patients with clinical suspicion of CVST (8 males and 19 females) ranging between 2 to 67 years of age (mean age 40.96; median 44) had undergone both CT and MR imaging consecutively. Ten of the 27 patients (44.4%) had a final diagnosis of CVST. Headache was the most consistent clinical symptom, presenting in 90% of the patients diagnosed with CVST (Table 1).

Comparison of the anatomical visualization of the dural venous sinus

Anatomical visualization of the dural venous sinus for 16–slice MDCTV and various field-strength TOF MRV for the 17 non-thrombotic subjects was assessed. On MDCTV, the Neuroradiologists were able to identify confidently the superior sagittal sinus (SSS), straight sinus, internal cerebral vein (ICV), vein of Galen (VOG) and both Trolard veins in all 17 subjects, the inferior sagittal sinus (ISS) in 64.7%, the right transverse sinus (right TS) in 94.1% and the left transverse sinus (left TS) in 76.5%. The visualization rate for TOF-MRV

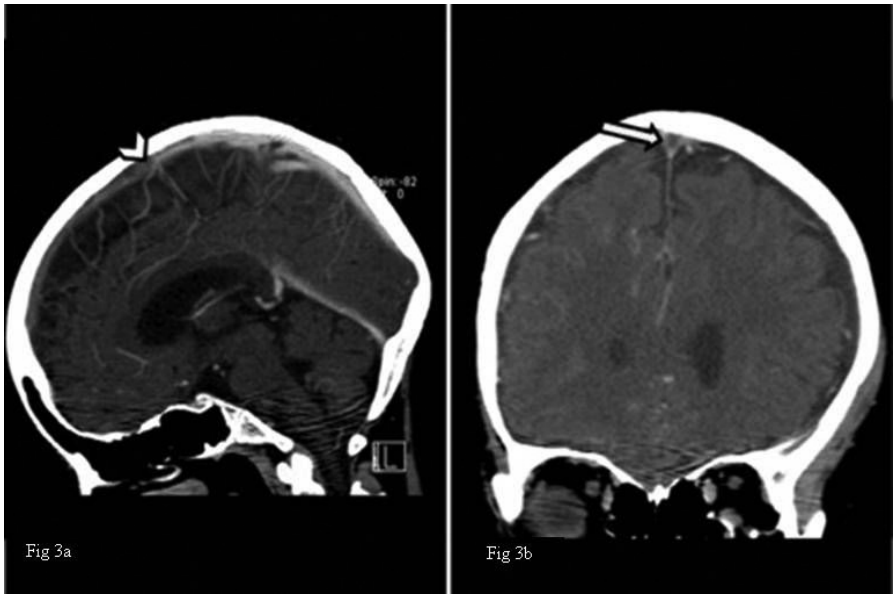

Figure 3. Superior sagittal sinus thrombosis. Figure 3a. CTV in reformatted sagittal plane showing hypodense filling defect within the anterior ½ of superior sagittal sinus (white arrowhead). Figure 3b. Triangular shaped 'Delta sign' of the similar thrombus (white arrow) in reformatted coronal plane of the CTV.

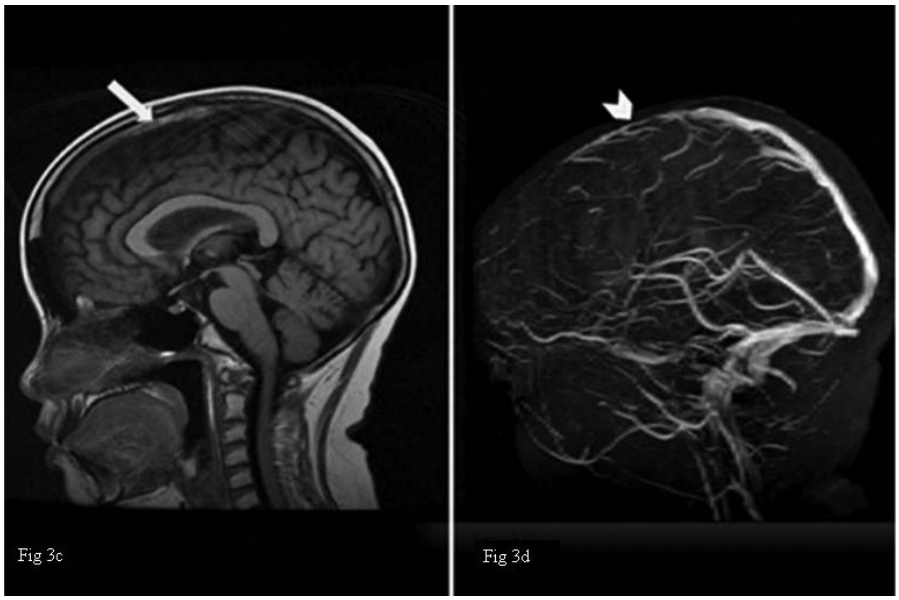

Figure 3c. T1-weighted sagittal image showing a hyperintense thrombus (white arrow) within the anterior ½ of superior sagittal sinus. Figure 3d. The thrombus is shown on the 2D-TOF MRV as a focal flow void abnormality (white arrowhead).

images was significantly lower with only 64.7% of SSS, 23.5% of ISS, 58.8% of straight sinus, 76.5% in ICV and 64.7% of VOG identified. The detection rates for right TS were 94.1% and 100% for both Trolard veins (Table 2). The left TS were poorly visualised (64.7%). There was no statistical difference in the anatomical visualization rate among the various strengths of MRI (Table 2).

Based on Wilcoxon Signed Ranks Test,

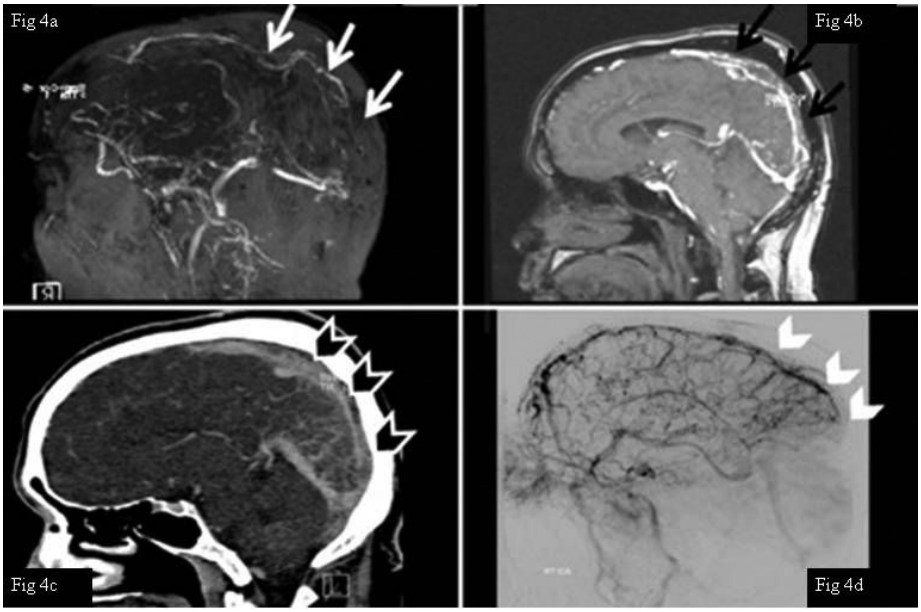

Figure 4a. 2D-TOF MRV lateral projections showing poorly opacified superior sagittal sinus (SSS) (white arrows). Contrast enhanced sagittal T1-weighted MR image (black arrows) (4b); Sagittal reformatted CTV image (4c) demonstrated filling defects along the SSS (black arrowheads). Figure 4d. Venous phase of the cerebral angiogram shown in lateral view confirmed filling defects within the posterior ½ of SSS in keeping with thrombosis (white arrowheads).

Table 1: Summary of clinical features, final-diagnosis and treatment

Pt	Age (yr)	Sex	Clinical Symptoms	Final diagnosis of CVST	Anti-coagulant Treatment	Final-diagnosis
1	56	F	Headache, seizures	Negative	No	ACOM and Right MCA aneurysm
2	58	F	Headache	Negative	No	Vasculitis with ICB and multifocal infarcts
3	19	F	Headache, seizures	Negative	No	Epilepsy
4	59	F	Blurr vision	Negative	No	Ischemic optic neuropathy
5	38	M	Headache, vomiting, blur vision, abducens nerve palsy	Negative	No	Lt periorbital cellulitis and ethmoid sinusitis causing bacterial meningitis
6	51	M	Headache, memory loss	Positive	Yes	ISS and vein of Galen thrombosis
7	43	F	Headache, past sinus thrombosis	Positive	Yes	Residual SSS and straight sinus thrombosis
8	35	F	Headache, vomiting, fever, loss of consciousness	Positive	No	SSS thrombosis due to bacterial meningitis with underlying diabetes mellitus
9	36	F	Headache, confusion, Fits, per vaginal bleed	Positive	Yes	SSS, Lt TS and Lt sigmoid thrombosis due to transxenamic acid treatment for menorrhagia
10	5	M	Headache, confusion, vomiting, seizures	Negative	Yes	PRES due to streptoccocus acute glomerulonephritis
11	46	M	Headache, vomiting, paraparesis	Negative	Yes	Multifocal infarcts due to ACA stenosis
12	59	F	Headache, vomiting, confusion	Negative	No	Left frontal lobe abscess with meningitis and cerebral oedema
13	67	F	Hemiparesis	Negative	No	Multifocal infarcts
14	28	F	Headache, vomiting	Negative	No	Migraine
15	38	F	Headache, blur vision	Negative	No	Multifocal infarcts including occipital regions
16	2	F	Confusion, seizures	Negative	No	Encephalitis with thalamic infarcts on immunosuppression for ulcerative colitis
17	18	F	Fits	Positive	Yes	SSS and both TS thrombosis; SLE with acute glomerulonephritis, acute renal failure, cerebral lupus
18	54	M	Seizures, fever, hemiparesis	Negative	No	Acute pancreatitis; end stage renal failure on haemodialysis
19	56	F	Headache, blur vision, seizures	Positive	Yes	Rt Tx sinus thrombosis
20	44	M	Headache, seizures	Positive	Yes	SSS, Rt TS, Rt sigmoid thrombosis with dural AV fistula
21	59	F	Headache, seizures	Positive	Yes	SSS and ISS thrombosis
22	44	M	Headache, fever, blur vision	Negative	Yes	Was treated as vein of Galen thrombosis based on initial CTV/MRV report; patient defaulted follow up
23	49	F	Hemiparesis, dysarthria	Negative	No	Intravascular lymphoma
24	43	F	headache	Negative	No	Migraine
25	41	F	Headache, meningioma	Positive	No	SSS and Rt TS thrombosis; meningioma and incidental pituitary adenoma
26	45	F	Headache, vomiting, blur vision	Negative	No	Epilepsy; hypothyroidism post thyroidectomy
27	13	M	Headache, seizures	Positive	Yes	SSS thrombosis with underlying leukaemia

Pt, patient; F, female; M, male; Lt, left; Rt, right; SSS, superior sagittal sinus; ISS, inferior sagittal sinus; TS, transverse sinus; ICB, intracranial bleed; ACOM, anterior communicating artery; ACA anterior cerebral artery; MCA, middle cerebral artery.

there were negative Z-values implying a lower frequency of visualised vessels in MRV compared to MDCTV (Table 2), which were statistically significant ($p<0.05$) for the SSS, ISS, straight sinus, ICV and VOG. However, there was no significant statistical difference ($p>0.05$) in either TS or both the Trolard veins between these different imaging modalities (Table 2). In summary, TOF-MR visualization of superficial venous structures, such as Trolard veins and the TS, was acceptable whereas the visualization of deep cerebral venous system (ICV, VOG, straight sinus and deeply located dural sinus of the ISS) was less favourable. MR flow artefacts rendering poorer image quality marred the TOF-MR images of the SSS.

Comparison between MDCTV and various field-strength MRV in patients with CVST

The final-diagnosis showed that 10 out of 27 patients (37%) had CVST (Table 1). In the MRV protocol, based on the reference standard (final-diagnosis), CVST was diagnosed in 5 out of 19 patients that had undergone 1.5T scanners (both the Magnetom Vision MR – Siemens and MR Signa EXCITE – GE), 3 out of 4 subjects using the 0.35T system (Magnetom C! Siemens) and another 2 out of 4 patients using the latest 3.0T field strength MRI (MR Signa HDx – GE). Furthermore, CVST was diagnosed in 1 out of 12 patients using GE® (General Electric) Lightspeed-16, whereas, 9 out of 15 patients were positive for CVST in another group who underwent Siemens Somatom Sensation-16.

Sensitivity and specificity study of MDCTV and various field-strengths MRV

The MDCTV (both 16-slice GE-Lightspeed and Siemens-Somatom) correctly identified 10 cases of sinus thrombosis out of 10 patients with a final-diagnosis of CVST determined by the reference standard, with a sensitivity rate of 100%. In the absence of any flow void to suggest sinus thrombosis, the specificity was determined at 94.1%. There was one case of false-positive (patient 12) and no false-negative phenomenon for 16-slice MDCTV, hence the false-positive rate and false-negative rate was 5.9% and 0%, respectively. The false positive was caused by a large round-shaped 7 mm giant arachnoid granulation mimicking the thrombus (Figure 5). The positive / negative predictive values were almost similar at 90.9% / 100% respectively for 16-slice MDCTV (Table 3).

The various field-strength MR studies showed a sensitivity of 100% by correctly identifying 10 cases of the CVST by final-diagnosis. There were three false positive cases (patient 10, 11 and 18) with specificity rate of 82.4% and false-positive rate of 17.6%. With regards to the three

Table 2: Anatomical structure comparison between MDCTV and MRV for 17 patients with no cerebral venous sinus thrombosis

	% visualized structure		Wilcoxon Signed Ranks Test	
Dural Sinus	**MDCTV**	**MRV-TOF**	**Z value MRV vs MDCTV**	**P value**
SSS	100%	64.7%	-2.449	0.014
ISS	64.7%	23.5%	-2.646	0.008
Straight sinus	100%	58.8%	-2.646	0.008
Rt transverse sinus	94.1%	94.1%	0	NS
Lt transverse sinus	76.5%	64.7%	-1.414	NS
Rt Sigmoid sinus	Excluded in comparison due to technical reason			
Lt sigmoid sinus	Excluded in comparison due to technical reason			
Internal cerebral vein	100%	76.5%	-2.0	0.046
Vein of Galen	100%	64.7%	-2.449	0.014
Rt Trolard	100%	100%	0	NS
Lt Trolard	100%	100%	0	NS

NS = Not significant; Lt, left; Rt, right; SSS, superior sagittal sinus; ISS, inferior sagittal sinus

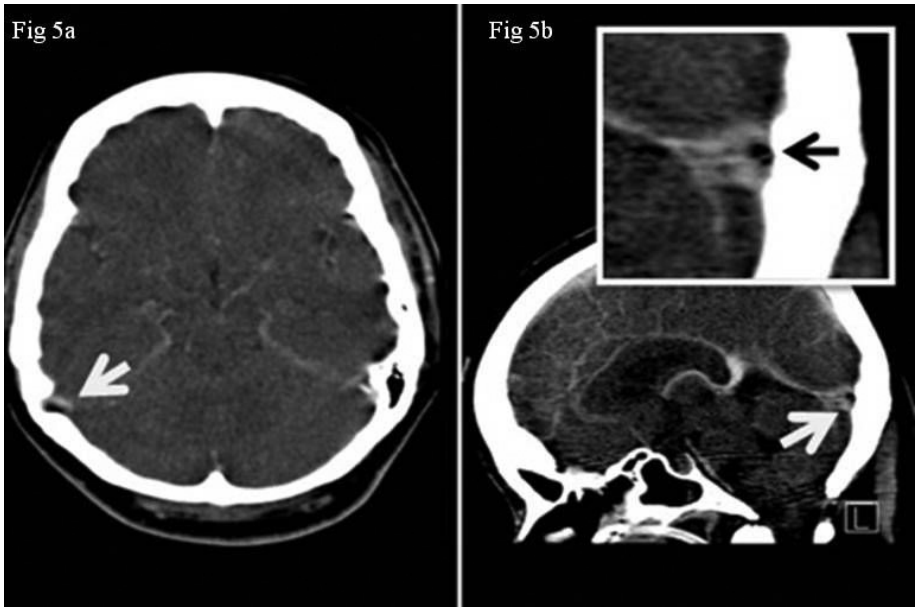

Figure 5a. CTV image in axial plane showing filling defect due to a spherical –shaped arachnoid granulation (white arrow) within the right transverse sinus mimicking sinus thrombosis. Figure 5b. Sagittal reformatted view of the similar giant arachnoid granulation (white arrow), careful examination of the lesion showing an internal vein (black arrow) in the magnified view.

false-positive cases in MRV, two of these (patient 11 and 18) demonstrated flow void artefact in 2D-TOF sequences due to in-plane signal loss that mimicked sinus thrombosis in the superior sagittal sinuses. Another false-positive MRV case was due to high Torcula bifurcation, located just above the cisterna magna that had caused partial voluming artefact at the proximal left transverse sinus mimicking the filling defect in the MRVs. One patient initially diagnosed with thrombosis at the vein of Galen (Figure 6a-c) was actually shown to have a pronounced V-shaped confluence of a pair of vein of Galen (Figure 6d) mimicking the appearance of thrombosis. There was no false negative case seen in the MRV. The positive / negative predictive values were calculated at

Table 3: Comparison of sensitivity and specificity of MDCTV and various field-strengths MRV

	CT venography		**MR venography**		
Modality	**16sliced MDCTV** GE-Lightspeed & Siemens-Somatom (n=27)	**Combined 0.35T, 1.5T, & 3.0T** (n=27)	**0.35 T** Siemens-Magnetom C! (n=4)	**1.5T** Siemens Magnetom-Vision & GE-MR Signa Excite (n=17)	**3.0T** GE-MRSigna HDx (n=4)
Sensitivity	100%	100%	100%	100%	100%
Specificity	94.1%	82.4%	100%	78.6%	100%
False positive rate	5.9%	17.6%	0%	21.4%	0%
False negative rate	0%	0%	0%	0%	0%
Positive predictive value	90.9%	76.9%	100%	62.5%	100%
Negative predictive value	100%	100%	100%	100%	100%

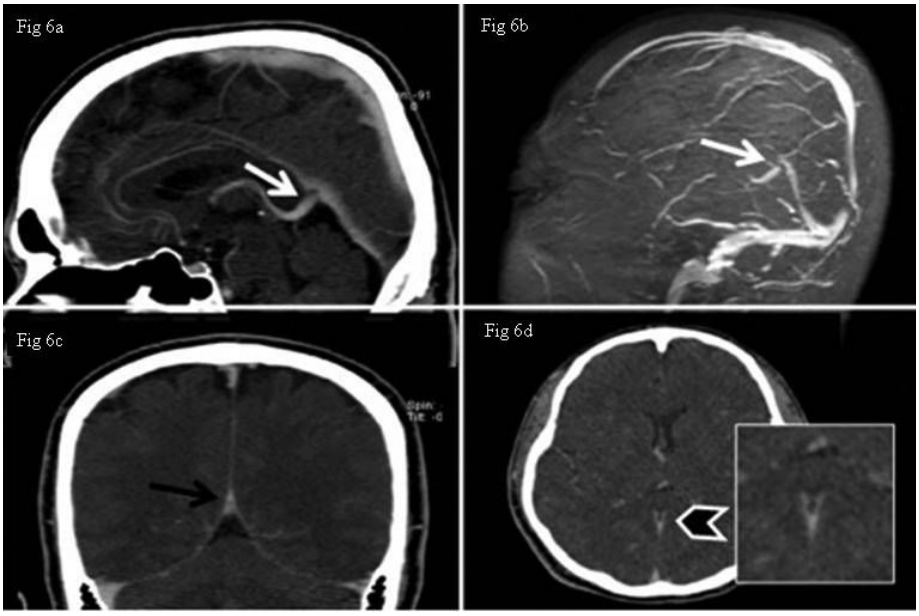

Figure 6a. Sagittal reformatted CTV and 2D-TOF MRV projection (6b) showing filling defect at the confluence of vein of Galen and the straight sinus (white arrow) suspicious of presence of a thrombus.
Figure 6c. Coronal reformatted CTV demonstrating the corresponding filling defect (black arrow).
Figure 6d. Careful examination of the CTV in axial plane showed V-shaped confluence of the vein of Galen (black arrowhead) mimicking a filling defect.

76.9% / 100% (Table 3). The three false positive cases were performed in the 1.5T MRI (Siemens-Magnetom Vision and GE-MR Signa EXCITE) and the likely explanation was that this represented the largest subgroup (n=19). The open-system MR 0.35T Magnetom C! Siemens and the high end 3.0T MR Signa HDx – GE accurately diagnosed three true positive and two true positive cases, respectively, with sensitivity as well as specificity rates of 100% (Table 3). Thus, the various field-strengths of MR did not appear to hinder the diagnosis of CVST in this study. However, this apparent accuracy may not be reliable due to the small number of patients in these 0.35T and 3.0T groups.

DISCUSSION

Generally, more anatomical sinuses and cerebral veins were visualised on the 16-slice MDCTV compared to MRV. Comparing the images of the deep vessels, such as the inferior sagittal sinus, straight sinus, internal cerebral vein and vein of Galen, MDCTV was superior to the MRV. In this study left transverse sinuses were poorly visualized compared to the right in both CTV and MRV, consistent with other studies.[4,6-8] This is likely due to the anatomical variant of atresia or hypoplasia or flow gap artefacts of the non-dominant vessels as described in the literature.[4,8] On the other hand, the superficial veins of Trolard were consistently visualised in both the MRV and CTV with sensitivity of 100%. The superior sagittal sinus was only visualised in 64.7% of the MRV due to occurrence of MR flow artefacts.

Previous studies has described MRV as the non-interventional gold standard in diagnosing CVST.[1,2,4,5] We found that the sensitivity rate for 16-slice MDCTV was at par with the MRV. In particular, MRV has a higher false positive cases compared to MDCTV. When the false positive cases were reviewed we found that these were due to 2 main factors. Firstly, the anatomical variance that could occur in both CTV and MRV such as a giant arachnoid granulation.[6,9,10] An important distinguishing feature to look for is the eccentric internal vein (Figure 5b) which was described to be present in up to 97% of all the arachnoid granulations studied.[10] Another anatomical variance is high Torcular bifurcation located above cisterna magna or pronounced V-shaped confluence of a pair of vein of Galen. These imaging pitfalls could have been avoided if the filling defect was verified in the coronal and axial planes of the multiplanar reformatted images of both CTV and MRV.

The other factor contributing to false positive result was technical, attributed to flow void artefact occurring in 2D-TOF sequences secondary to in-plane signal loss.[11-13] One solution to overcome this is by performing single-slice thick slab Phase Contrast (PC)- MRV of the midline sagittal brain which would opacify the superior sagittal sinus. Adam *et al*[13] in a study of thick slab PC-MRV images of 23 patients with 14 positive cases showed a 100% sensitivity and specificity rate in diagnosing sinus thrombosis. However, Widjaja *et al*[14], stressed that PC-MRV suffers from potential lack of sensitivity to slow flow if selected velocity encoding of the venous flow is incorrect. The velocity of blood flow in the dural sinuses in neonates (9.2cm^3/sec) was slower compared to older children and adults (20cm^3/sec) as described in colour Doppler studies.[14]

Towards the end of study, due to perceived common occurrence of arachnoid granulations mimicking the flow void of intraluminal thrombus as well as the encountered vascular variants, a new imaging MRV sequence of gadolinium-opacified MPRAGE (3-dimensional gradient echo sequence) images of the midline structures were performed on four patients which showed increased clarity of the arachnoid granulation with visualization of the internal vein (Figure 7d).

With improved contrast resolution of newer imaging techniques, the use of thin slice contrast -enhanced MR venography and three dimensional gradient recalled echo (GRE) sequences could reliably differentiate intraluminal thrombus, arachnoid granulations and flow related enhancement artefacts.[6,15] A recent study by Meckel *et al* found that contrast enhanced 4D MR venography showed the highest diagnostic accuracy for thrombosed dural sinuses compared to 2D- TOF MRV, GRE and T2-weighted sequences.[16] Thus, it is always a good practice to supplement the findings of 2D-TOF MRV with the thick slab PC-MRV images while analyzing opacification of the midline structures of SSS, ISS, ICV and VOG.

In conclusion, MDCTV is equal to MRV in its sensitivity for CVST diagnosis and superior to non-contrasted MRV in the visualization of the venous structures. The various strength magnets do not affect the sensitivity for detecting CVST in 2D TOF-MRV.

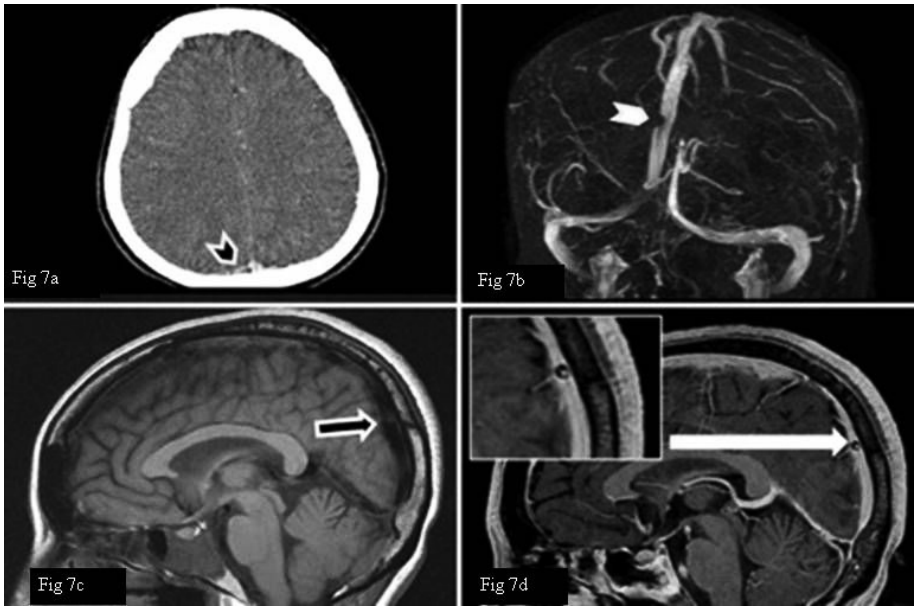

Figure 7a. CTV in axial plane showed a filling defect within the superior sagittal sinus (SSS) (black arrowhead). Figure 7b. 2D-TOF MRV projection showed a similar nodular filling defect indenting the sidewall (white arrowhead). Figure 7c. On sagittal T1-weighted image, there was an isoechoiec signal intensity seen within the SSS (black arrow) mimicking a thrombus. Figure 7d. Contrast-enhanced MPRAGE sagittal image confirmed the filling defect with associated internal vein (white arrow) (enlarged inset image). These findings are consistent with pacchonian arachnoid granulation.

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