Accuracy of conventional MR sequences, un-enhanced MR venography and contrast-enhanced 3D GRE T1-weighted imaging in evaluation of dural venous sinus and cortical venous thrombosis, stenosis and non-thrombotic filling defect

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Aims and objectives

Cerebral dural venous sinus (DVS) thrombosis is a relatively uncommon disorder when compared with other stroke etiologies. It occurs in three to four people per one million and is responsible for nearly 1-2% of strokes in young adults [1,2]. Its incidence is probably underestimated due to lack of noninvasive accurate imaging modalities and challenging interpretation of DVS thrombosis [3,4]. Early diagnosis and treatment are crucial for accurate management. Symptoms and survey of DVS thrombosis depend on duration, extension and location of thrombosis [4]. Therefore, early diagnosis and explaining location and extension of the thrombosis are very important.

Magnetic resonance imaging (MRI) is frequently performed to detect cerebral DVS thrombosis due to its superiority in evaluation of not only the DVS thrombosis itself, also cerebral parenchymal pathologies [5]. Currently, most commonly used MRI techniques are conventional sequences and un-enhanced MR venography such as time-of-flight (TOF) and Phase-contrast (PC), and contrast-enhanced MR venography [3].

Volumetric three-dimensional (3D) gradient recalled echo (GRE) T1-weighted sequences are relatively the best MRI sequences, especially contrast-enhanced images, in evaluation of the DVS and cortical veins. GRE MR sequences allow acquisition of T1-weighted 3D data sets of the brain that can be reformatted to provide images in different orientations by using a process called multiplanar reconstruction [6]. For this purpose, slices of 1 mm thickness are gained with isotropic voxels. This allows high spatial resolution and less flow artifacts due to its GRE nature in a reasonable time for clinical use.

The aim of this presentation was to compare the diagnostic value of conventional MRI sequences, un-enhanced MR venography and contrast-enhanced 3D GRE T1-weighted images in detection of the DVS and cortical venous thromboses, and to determine the relationship among DVS thrombosis, gender, age, thrombus location, infarction and hemorrhage.
Methods and materials

Patients

Approval for this retrospective study was obtained from the institutional review board. Informed patient consent was not required for retrospective review of medical records and imaging studies. We included all patients with DVS and/or cortical venous thromboses in our institution between January 2011 and October 2014 and in whom an MRI with non-contrast MR venography and contrast-enhanced 3D GE T1-weighted sequence were performed. Patients with (i) acute or chronic DVS and/or cortical venous thrombosis diagnosed according to clinical presentation, conventional brain MRI, non-contrast MR venography, contrast enhanced MR venography and/or digital subtraction angiography; and who has (ii) MRI examination including conventional MRI, non-contrast MR venography and contrast enhanced 3D GE T1-weighted sequences performed within same day were included in the study. The exclusion criteria were incomplete MRI examination and inadequate image quality for diagnostic purposes. This search revealed 30 consecutive patients who met the inclusion criteria in 4 years period.

MRI Technique

MRI was performed in 3 T (Achieva X-Series; Philips Healthcare, Best, the Netherlands) or 1.5 T (Intera Nova, Philips Medical Systems, Best, the Netherlands) MR scanners by using standard head coil. MRI protocol began with localizing sequences and continued with conventional axial and sagittal SE T1; axial turbo spin-echo (TSE) T2, fluid-attenuated inversion recovery (FLAIR), GE T2*, diffusion weighted imaging (DWI); coronal fat-suppressed TSE T2 sequences. Then, un-enhanced PC MR venography protocols continued in axial or coronal plane. Subsequently, a standard dose (0.1 mmol/kg) of gadoterate meglumine (Dotarem; Guerbet, Roissy, France) was administered at a rate of 2-3 mL/s in all patients via antecubital vein. 3D GRE T1-weighted imaging sequences (magnetization prepared rapid acquisition gradient-echo) were performed in the sagittal plane.

Evaluation of MR images

For each of the 30 patients, the imaging sequences were separated into three datasets. The first dataset consisted of the conventional MR scans including axial, coronal, and sagittal un-enhanced SE T1-, TSE T2-, axial GE T2*-weighted and FLAIR sequences. The second one was consisted of un-enhanced MR venography examination including axial source images and rotating MIP reconstructions of PC MR venography. The third and the last one was consisted of sagittal 3D GRE T1-weighted imaging examination and its axial and coronal reformatted images. Consequently, 90 datasets were formed for assessment. Three independent blinded sessions of image interpretation were performed at least 2 weeks apart to avoid recall bias. Each dataset was evaluated on the same workstation by two experienced radiologists who were blinded to patient information,
diagnosis and the findings on other imaging sequences at the same time, and final decisions were reached in consensus. For the 3D datasets, workstation was used to generate multiplanar displays.

Each dataset was scored for the presence or absence of thrombus in each of the following 10 venous segments: right and left internal jugular vein bulbs, right and left sigmoid sinuses, right and left transverse sinuses, anterior half of superior sagittal sinus (anterior of the central sulcus), posterior half of superior sagittal sinus (posterior of the central sulcus), sinus rectus and cortical veins.
Results

The 30 patients (21-70 years old, mean age 40.1) with DVS thrombosis or stenosis or non-thrombotic filling defect were included in this study. 17 patients were male (mean age, 35.6 years; age range, 21-70 years), and 13 patients were female (mean age, 46.1 years; age range, 42-70 years). According to final diagnosis regarded as gold standard, there were DVS and/or cortical venous thromboses in 24 (80%) cases. In the rest of the cases (n=6, 20%) stenosis of the DVS, filling defects due to causes other than thrombosis such as arachnoid granulations, or DVS hypoplasia/aplasia were determined. These 6 cases were not excluded to achieve accurate true positive, true negative, false positive, false negative values. Among these 30 cases, there were venous infarcts in 8 cases, parenchymal or subarachnoid haemorrhages in 11 cases, isolated or accompanying cortical venous thromboses in 9 cases, and anatomical variations of the DVS in 9 cases. The most frequently encountered anatomical variation of DVS was hypoplasia of the left transverse sinus that is seen in 6 cases. In a case hypoplasia of the left transverse and sigmoid sinuses, and in two cases hypoplasia of the either right or left sigmoid sinuses were determined.

54.2% (13/24) and 45.8% (11/24) of the cases with DVS thrombosis were male and female, respectively. There was no statistically significant difference between genders (\(P=.672\), Chi-Square Test).

Between two groups, below and above age 40, there was no statistically significant difference in frequencies of the thrombosis, hemorrhage and venous infarct (\(P=1.00\), Chi-Square Test).

There was no statistically significant difference between genders according to frequencies of the anatomical variations, accompanying hemorrhage and venous infarct (\(P=1.00\), Chi-Square Test).

In 8 of the 9 cases with cortical venous thromboses that were isolated or associated with DVS thromboses, there were parenchymal or subarachnoid hemorrhages. In 5 of the 9 cases, there were venous infarcts associated with thromboses. In cases with cortical venous thrombosis, the frequency of the hemorrhage or venous infarct was statistically higher when compared with ones without cortical venous thrombosis (\(P<.001\) and \(P=.032\), Chi-Square Test).

According to our segmentation model, 300 segments of DVS and cortical venous structures were evaluated in each sequence dataset. In 67 (23.3%) of these 300 segments, there was thrombosis. On the other hand, in 233 segments (77.7%), there was
no thrombosis. Thrombotic segments were right transverse sinus (n=9), left transverse sinus (n=9), right sigmoid sinus (n=9), left sigmoid sinus (n=8), anterior part of the superior sagittal sinus (n=5), posterior part of the superior sagittal sinus (n=8), sinus rectus (n=2), right jugular bulb (n=4), left jugular bulb (n=4) and cortical veins (n=9). 56 of the 67 thrombotic segments (83.6%) were determined by the conventional MR sequences, whereas 11 of them (13.6%) were not. 11 of the 233 non-thrombotic segments were misinterpreted as thrombotic (false positive). 60 of the 67 thrombotic segments (89.6%) were determined as thrombotic by the un-enhanced MR venography, whereas 7 of them (10.4%) were not. 19 of the 233 non-thrombotic segments were misinterpreted as thrombotic (false positive). 62 of the 67 thrombotic segments (92.5%) were determined as thrombotic by the contrast-enhanced 3D GE T1-weighted sequence, whereas 5 of them (7.5%) were not. 2 of these 5 segments were cortical veins bearing hyperintense thrombosis, rest of them had hyperintense thromboses in DVS on un-enhanced T1 weighted SE sequences. Contrast-enhanced 3D GE T1-weighted sequence did not show any false positive results.

For the detection of the thrombotic segment, sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV) and accuracy were 83.6%, 95.7%, 84.8%, 95.3% and 93% in conventional MR sequences, 89.6%, 91.8%, 75.9%, 96.8% and 91.3% in un-enhanced MR venography, and 92.5%, 100%, 100%, 97.9% and 98.3% in contrast-enhanced 3D GE T1-weighted sequence, respectively.

Figures 1, 2, 3 and 4 show representative cases of concordance and discordance of each technique in patients with DVS and/or cortical vein thrombosis.
Fig. 1: 41-year-old woman who presented with headache. Coronal TSE T2-weighted image (a) shows hyperintense signal in right transverse sinus (arrow). Oblique transverse MIP image from coronal PC MR venography (b) shows absent flow signal in right transverse sinus. Right sigmoid sinus is visible on PC MR venography image. Axial (c), coronal (d) and sagittal (e) contrast-enhanced 3D GRE T1-weighted images show a tiny, well defined, iso-intense with CSF filling defect (arrowhead) in right transverse sinus consistent with small arachnoid granulation that has adjacent cortical veins and CSF space continuation. However, both transverse sinuses are normally filled with contrast. In this case, contrast enhanced 3D GRE T1-weighted sequence correctly showed arachnoid granulation and patency of the DVSs, but conventional T2-weighted sequence and PC MR venography showed false positive results for right transverse sinus.
Fig. 2: Acute superior sagittal sinus, right transverse and sigmoid sinuses and cortical venous thrombus in a 39-year-old man with a severe headache and nausea for 4 days. Axial T1-weighted MR images (a,b) show iso to hyperintense signal in superior sagittal sinus and hyperintense signal in right cortical veins (arrow) consistent with thrombus. Parenchymal hemorrhagic venous infarction area containing hyperintense subacute hemorrhagic signals are also seen. Contrast enhanced 3D T1-weighted axial (c) and sagittal (d) images show empty delta sign in the superior sagittal sinus consistent with thrombosis. However, right cortical venous thrombosis (arrow) is not diagnosed on this image due to intrinsic hyperintense signal of the thrombus (false negative case for 3D GRE T1-weighted image). Frontal MIP image obtained from coronal PC MR venography (e) shows lack of flow in superior sagittal sinus, right transverse and sigmoid sinuses (arrows).

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Fig. 3: 68-year-old woman who presented with headache and altered mental status. Axial (a) and coronal (b) SE T2-weighted images show hyperintense signal void due to intrinsic hyperintensity of thrombus in right transverse and sigmoid sinuses (arrows). Signal void appearance of left transverse and sigmoid sinuses are seen consistent with normal flow. (c) Frontal MIP image obtained from coronal PC MR venography shows absent flow signal in right transverse and sigmoid sinuses due to thrombus. However, left transverse sinus is also very thin and may be consisted with partial thrombus or long segment stenosis. Coronal (d) and sagittal (e,f) contrast-enhanced 3D GRE T1-weighted images show filling defect (arrow) in right transverse sinus consistent with thrombosis. However, left transverse sinus is normally enhancing and open in d and f. In this case, conventional sequences, PC MR venography and contrast enhanced 3D GRE T1-weighted sequence correctly showed thrombus in right transverse and sigmoid sinuses, but PC MR venography showed false positive result for left transverse sinus.

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Fig. 4: 48-year-old man who presented with progressive headache, nausea and altered mental status for 24 hours. Coronal (a) and axial (b) T2-weighted images show no signal void in left transverse and sigmoid sinuses due to hypointense acute thrombus (arrows). The right transverse and sigmoid sinuses show prominent hypointensity that is interpreted as signal void appearance of normal flow (arrowheads). Sagittal (c), coronal (d), and axial (e) contrast-enhanced 3D GRE T1-weighted images show filling defect (arrows) in posterior part of the superior sagittal sinus, both transverse and sigmoid sinuses and jugular bulbs. In this case, conventional T2-weighted sequence missed the thrombus in right transverse and sigmoid sinuses and jugular bulb due to prominent hypointense signal of acute thrombus on T2-weighted images. Contrast enhanced 3D T1-weighted sequence correctly showed all thrombotic segments.

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Conclusion

In conclusion, contrast-enhanced 3D GE T1-weighted MRI is the most effective imaging method for the detection of the thrombus in patients with DVS and/or cortical venous thrombosis. Contrast-enhanced 3D GE T1-weighted sequence has high sensitivity, specificity and accuracy, and can be obtained in 5-7 minutes. However, conventional MR sequences and MR venography may provide additional information in some cases including isolated cortical venous thrombosis and in case with early subacute thrombus material that is hyperintense on T1- and hypointense on T2-weighted images. Since, accompanying haemorrhage and infarctions are more frequently seen in cases with cortical venous thrombosis, isolated or associated cortical venous thrombosis should be evaluated carefully in these cases.
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References


