Comparison of diagnostic value of CT-venography and MR-venography in diagnosis of neonatal sinus vein thrombosis

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Aims and objectives

Cerebral sinovenous thrombosis (CSVT) is an important cause of pediatric stroke, which is potentially reversible with a prompt diagnosis and appropriate treatment [1]. The incidence of CSVT in children is 0.67 cases per 100,000 children/year; and it affects primary neonates, representing 43% of those cases [2]. Both term and premature infants are at risk [3], with neonates in NICU being at the highest risk to develop CSVT [3, 4].

Previous studies demonstrated that CSVT is not well tolerated in children, particularly in neonates [1]. Neonates have a higher percentage of parenchymal damage [1, 5] with mortality rates of 6-19% [4, 5]. Improperly treated newborns can have a very poor outcome with general developmental delay, sensorimotor deficit, visual impairment and epilepsy [6]. However, early diagnosed and properly treated CSVT is potentially reversible with a full recovery and no neurological sequelae.

Because CSVT does not have specific clinical manifestations [7], the diagnosis is primary based on imaging findings [8]. CT and MR-venography are the main diagnostic imaging modalities in suspected neonatal CSVT, however, there is still no consensus which of these studies is the method of choice. Therefore, we decided to undertake a retrospective study of the comparative diagnostic value of MRV and CTV for neonatal CSVT.

The aim of our study is to compare the diagnostic value of CTV and TOF MRV in the diagnosis of neonatal CSVT, to optimize the CT and MRI protocols for suspected CSVT and to describe possible pitfalls of each method and find ways to avoid them. In contrast to most studies on pediatric CSVT, which include children of all ages, our study is dedicated to the imaging of CSVT exclusively in neonates.
Methods and materials

This is a single-center retrospective study, which has been approved by our institutional research ethics board.

Patient selection:

Cases were identified through the SickKids Children's Stroke Program between January 1994 and December 2011.

Inclusion criteria:

The inclusion criteria were neonates (birth to 28 days, term, and preterm) with presumed CSVT, who during their investigation underwent both MRV and CTV- in total 63 neonates.

Exclusion criteria:

We excluded patients who had more than a 24 hour time interval between the two exams, patients with poor quality exams, as well as patients who only had hard copies of their studies.

The final study population included 16 out of the original 63 neonates (12M: 4F).

Clinical data collection:

Clinical data for CSVT cases was obtained from systematic data collection protocols within the SickKids Children's Stroke Program. These data included gender, neuroimaging indicators, age at radiographic CSVT diagnosis (early [<7 days] versus late [8-28 days]), weight, head circumference, type of delivery (vaginal or c-section), risk factors for CSVT, final diagnosis, anticoagulation treatment and outcome.

Radiographic data collection:

We used a GE PACS system.

Two certified pediatric neuroradiologists, blinded to clinical data, independently reviewed each initial CT/CT venography and MR/MR venography for cerebral sinovenous thrombosis location, extent (single/multiple sinus, occlusive/nonocclusive). Unenhanced and contrast-enhanced CT images, each MRI sequence and MRV source images were reviewed separately. Assessment of each venous structure was performed separately regarding the presence of thrombosis: the superficial venous system, superior sagittal
sinus divided into proximal, middle and posterior thirds, transverse sinuses divided into proximal and distal halves, torcular Herophili, sigmoid sinuses divided into proximal and distal, internal jugular veins; deep venous system: deep basal veins, internal cerebral veins, Vein of Galen, straight sinus.

**CTV technique:**

CT/CTV studies were performed on 8-row multidetector CT (LightSpeed Ultra; GE Healthcare). Unenhanced and contrast-enhanced CT scans were performed in 15 patients and direct contrast-enhanced scans - in 1 patient. Contrast-enhanced scans were obtained with CTV protocol after IV hand injection of a 2.5 mL/kg bolus of iohexol USP 65% (Omnipaque 300; GE Healthcare, Oakville, Canada). The studies were performed with a section thickness of 5 mm, x-ray tube voltage of 120 kV, x-ray current of 80 mA, 2 images per rotation, and a FOV of 22 cm. Contrast-enhanced axial images were reconstructed at 1.25 mm, with coronal and sagittal MPRs (Fig. 1). Unenhanced CT scans of the patients were analyzed for the presence of increased density within the dural sinuses and veins. CT venograms were analyzed for filling defects in the dural sinuses.

![Fig. 1: CTV technique.](image)

**References:** Diagnostic Imaging, The Hospital for Sick Children - Toronto/CA
**MRV technique:**

MRI/MRV studies were performed on 1.5 T scanners.

MRI protocols included: DWI, axial and sagittal T1, axial and coronal FSE T2 in all patients. Additional sequences were obtained on the basis of clinical indication and MR findings and included GE and SWI in 9 patients. Coronal 2D time-of-flight MRV with 3D MIP reformats were obtained in all patients (Fig. 2). The parameters were: TE, 5 to 6 ms; TR, 50 ms; flip angle, 60°; section thickness, 1.5 mm; matrix, 256 X160; and FOV, 20 cm.

![MRV imaging](image_url)

**Fig. 2:** MRV technique.

**References:** Diagnostic Imaging, The Hospital for Sick Children - Toronto/CA

**Statistical Analysis:**

We used statistical software SAS 9.3. Rater and modality agreement were evaluated using Kappa Statistics [9].
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<tr>
<th>Kappa value</th>
<th>Agreement</th>
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**Table 1**: Kappa statistics

**References**: Diagnostic Imaging, The Hospital for Sick Children - Toronto/CA
Images for this section:

![CTV technique](image1.png)

**Fig. 1:** CTV technique.

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Fig. 2: MRV technique.

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Table 1: Kappa statistics

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Results

**Clinical findings:**

Clinical data are summarized in Table 2 on page 17.

Regarding time of disease onset: early presentation (on the first postnatal week) was seen in 10 patients (62.5%); late presentation (during the subsequent 3 weeks) - was seen in 6 patients (37.5%).

Overall, 12 patients (75%) had seizures (isolated or in combination with other symptoms), which were the most common presenting symptoms.

Two patients died (mortality rate - 12.5%).

**Radiographic findings:**

Isolated superficial venous structures were involved in 9 (56.25%) patients (Fig. 3 on page 17; Fig. 4 on page 18); isolated deep venous structures were involved in 1 (6.25%) patient and simultaneous deep and superficial venous structures were involved in 6 (37.5%) patients (Fig. 5 on page 18; Fig. 6 on page 19).

Multiple venous structures involvement was in 12 (75%) patients (Fig. 7 on page 20; Fig. 8 on page 21) and single venous structure was involved in 4 (25%) patients (Fig. 3 on page 17; Fig. 4 on page 18).

Intracranial bleed was found in 12 (75%) patients (Fig. 5 on page 18; Fig. 6 on page 19).
**Fig. 7**: Sample case 3. CT of a 6-day-old male neonate after vacuum delivery and multifocal seizures. A, B, C- Axial slices from the unenhanced CT-scan, as part of our CTV protocol, demonstrate increased density within the torcula (*), straight sinus (black arrow), vein of Galen (white arrow) and internal cerebral veins (paired arrowheads) in keeping with thrombosis. D, E, F-contrast-enhanced scan with CTV protocol: axial slices (E, F) and sagittal MPR (D) demonstrate filling defect (*) within the thrombosed torcula as well as within the posterior third of the superior sagittal sinus. However, it is difficult to depict thrombosis of the deep venous structures: internal cerebral veins (arrowheads), vein of Galen (white arrow) and straight sinus (black arrow), which appear of similar density as the patent inferior sagittal sinus (dashed arrow) and patent anterior and middle thirds of the superior sagittal sinus (SSS). Comparison with pre-contrast images prevents this potential pitfall.

**References**: Diagnostic Imaging, The Hospital for Sick Children - Toronto/CA
Fig. 8: Sample case 3. MRI of a 6-day-old male neonate after vacuum delivery and multifocal seizures (the same patient as Fig. 7). J- Sagittal T1W images demonstrate increased signal within thrombosed internal cerebral veins (arrowhead), vein of Galen (white arrow) and torcula (*). H, I- Axial GE images demonstrate susceptibility artifacts within thrombosed internal cerebral veins (arrowheads) as well as within the straight sinus (black arrow) and torcula (*). J, K- Coronal and sagittal 3D reformats from coronal 2D TOF MRA demonstrate filling defect within the posterior third of the superior sagittal sinus and torcula (*) as well as lack of visualization of the internal cerebral veins, vein of Galen and straight sinus in keeping with thrombosis of these structures.

References: Diagnostic Imaging, The Hospital for Sick Children - Toronto/CA

Statistical results:

Overall, there was a substantial agreement between CTV and MRV for both raters: kappa=0.5639 for rater 1 (Table 3 on page 22, Fig. 9 on page 23) and kappa=0.6988 for rater 2 (Table 4 on page 24, Fig. 10 on page 25).
Fig. 9: Chart illustrating the agreement between CTV and MRV for rater 1.

References: Diagnostic Imaging, The Hospital for Sick Children - Toronto/CA
Substantial agreement was also seen between the raters for both CTV (Table 5 on page 26, Fig. 11 on page 27) and MRV (Table 6 on page 28, Fig. 12 on page 29) with kappa =0.6092 and 0.6435 for CTV and MRV, respectively.
Fig. 11: Chart illustrating the agreement between rater 1 and rater 2 for CTV.

References: Diagnostic Imaging, The Hospital for Sick Children - Toronto/CA
**Fig. 12:** Chart illustrating the agreement between rater 1 and rater 2 for MRV.

**References:** Diagnostic Imaging, The Hospital for Sick Children - Toronto/CA
Table 2: Clinical findings.

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**Fig. 3:** Sample case 1. CT of a 4-day-old male with suspected myoclonic seizures and a history of vacuum delivery and fetal distress. The only abnormality found on unenhanced CT (A, B, C) was a hyperdense occipital sinus (arrow) in keeping with thrombosis. However, on contrast-enhanced CTV (D, E, F) it is harder to depict signs of thrombosis of the occipital sinus (arrow) because the density of the thrombosed sinus and contrast opacified patent venous structures is similar. Therefore, we highly recommend including an unenhanced CT scan in the CTV protocol despite the risk of increased radiation.

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![CT images](image)

**Fig. 4:** Sample case 1. MRI of 4-day-old male with suspected myoclonic seizures and a history of vacuum delivery and fetal distress (the same patient as Fig. 3). A, B-sagittal and axial T1W images demonstrate the hyperintense thrombosed occipital sinus (arrow). However on TOF MRV (C, D) it is hard to differentiate between a hyperintense thrombosed occipital sinus (arrow) and flow within the patent superior sagittal and transverse sinuses; this is the so-called "thrombus signal shine-through" at TOF MRV. Comparison with T1 weighted images helps to avoid this potential pitfall.

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Fig. 5: Sample case 2. CT of a 2-week-old male with seizures and encephalopathy. A, B, C- Unenhanced CT demonstrates extensive thrombosis of the superficial and deep venous structures, including bilateral cortical veins (black arrows), superior sagittal sinus (SSS), torcular (*), straight sinus and internal cerebral vein (white arrows) thrombosis. There are associated bilateral thalamic (arrowheads) and basal ganglia (white dashed arrows) hemorrhages as well as massive intraventricular hemorrhage (h) resulting in hydrocephalus. D,E- Contrast-enhanced CTV of the same patient demonstrates filling defects within the superior sagittal sinus (SSS) and bilateral cortical veins (black arrows). Comparison with unenhanced scan helps to depict thrombosis of the torcular (*).

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Fig. 6: Sample case 2. MRI of a 2-week-old male with seizures and encephalopathy (the same patient as Fig. 5). Sagittal (A) and coronal (B) T1 images demonstrate hyperintensity within the superior sagittal sinus (SSS), bilateral transverse sinuses (dashed black arrows), straight sinus (black arrow) in keeping with thrombosis. C-GE image demonstrates susceptibility artifact caused by thrombosed ICVs (black arrowheads), as well as from the bilateral thalamic (white arrows) and intraventricular (h) hemorrhage. D-There is almost no visualization of flow within venous structures on TOF MRV. This patient died 5 days after presentation.

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Table 3: The agreement between CTV and MRV for rater 1.

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**Fig. 9:** Chart illustrating the agreement between CTV and MRV for rater 1.

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Table 4: The agreement between CTV and MRV for rater 2.

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**Fig. 10:** Chart illustrating the agreement between CTV and MRV for rater 2.

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**Table 5:** The agreement between rater 1 and rater 2 for CTV.

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**Fig. 11:** Chart illustrating the agreement between rater 1 and rater 2 for CTV.

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### Table 6: The agreement between rater1 and rater2 for MRV.

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Fig. 12: Chart illustrating the agreement between rater 1 and rater 2 for MRV.

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Conclusion

In our study, the comparison between CT/CTV and MR/TOF MRV showed substantial agreement between them, suggesting an equal diagnostic value of both techniques in the diagnosis of neonatal CSVT. Therefore, we feel that clinicians should be informed that both studies have a similar ability of depiction of CSVT radiographic signs and thus other parameters should be preferentially considered in making the choice between those two modalities. These factors could include the clinical status of the neonate (stable/unstable), risk of radiation and iodinate contrast-material exposure, and availability of MRV.

Limitations:

The main limitations of our study are its retrospective nature, the time-gap between CTV and MRV, as well as variations in study protocols. There is also a potential difference in the quality of the examinations, with older examinations possibly being expected of lower quality.
Personal information

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