Intracranial venous system Magnetic Resonance
Venography: Diagnostic radiological methods possibilities,
limitations and indications

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Purpose

1. The use of cerebral MR venography is increasing in frequency as a noninvasive means of evaluating the intracranial venous system. This technique is particularly useful in the diagnosis of venous sinus thrombosis, which at times can be difficult[1]. Patients with dural sinus thrombosis are encountered quite seldom in clinical practice. It is not only the presence of thrombosis in sinuses which can alter the appearance of normal anatomy of intracranial venous system but also presence of thrombosis in veins which can bring alteration. Other disorders like idiopathic intracranial hypertension can cause alteration by compressing on venous system, and moreover, in cases with congenital developmental anomalies like stenosis etc[2].

2. The purpose of this study is to evaluate the normal Intra-Cranial Venous (ICV) anatomy and its variants as depicted by Magnetic Resonance Venography (MRV) to facilitate the interpretation of these examinations and avoid potential pitfalls in correct evaluation of ICV structures, and which among the three methods 2D Time-Of-Flight (2D TOF), 3D Phase Contrast (3D PC), & Contrast Enhanced-Magnetic Resonance Imaging (CE-MRI) is most appropriate in appreciating anatomical ICV structures. It is important to be able to differentiate patho-radiological changes from apparent changes which could be owing to drawbacks and limitations of methods.
Methods and Materials

Materials:

This study was approved by our institutional review board. In this study so far 10 patients have been prospectively taken with varied intra-cranial pathologies not causing intra-cranial volume effect and could not be related to intra-cranial venous system. Age and sex of patients examined were as follows: age group 19-72 years; male/female, 20%/80%.

Methods:

1. These patients underwent MRV which included use of three methods/sequences 2D TOF, 3D PC and CE-MRI. The patients agreed to undergo CE-MRI as an additional sequence even when in some cases it was not indicated. This study did not have gold standard to be compared with, which is Digital Subtraction Angiography (DSA). In house scans were done on a 1.5 Tesla magnet involving above mentioned sequences and intra-cranial venous structures were studied after standard reconstructions were prepared using Maximum Intensity Projection (MIP) as shown in Figure 1 and 180 degrees rotational reconstructions in coronal and axial planes with angle between images 10 degree as shown in Figure 2. In our study slice thickness for 2D TOF method was 3 mm with distant factor -33%. 2D TOF technique was optimised by choosing a sagittal slice orientation tilted slightly towards coronal and axial directions. Examination time for 2D TOF in our study was 5 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[1] 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. In our study the usual examination time with 3D PC method was 6 minutes and 28 seconds, which is more than the time needed for carrying out 2D TOF or CE-MRI.

Two observers, one resident radiologist in training and second neuroradiologist with experience, studied these structures and made their observations independently. Their observations were compared by statistical method- Two-sample T-test.

2. The appearance of various intra-cranial venous structures was assessed in context of their signal intensity, uniformity and extent of dimension of the structure visible on three different Magnetic Resonance Venography (MRV) methods. Accordingly, values were assigned to each of them on different methods. These values ranged from 0-2 wherein they meant as follows:

- 0 - when structure was almost unnoticeable or very faintly visible without completeness,
• 1 - when structure is visible to some extent, or visible completely but narrowed inhomogenously or showing visible flow defects especially in case of sinuses,
• 2 - when structure is apparently visible without noticeable flow defects or incompleteness.

3. 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 Thalomostriate veins (TSVs), Vein of Galen (VG), Straight Sinus (SS), Inferior Sagittal Sinus (ISS). While structures from superficial venous system included in study are bilateral veins of Trolard (VTs) and among dural sinuses Superior Sagittal Sinus (SSS), bilateral Lateral Sinuses (LS), bilateral Sigmoid Sinuses (SGS), Torcular Herophili (TH). 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. Moreover, vein of Labbe which is one of the superficial veins is also visualized with all methods, hence, not included in study.

4. The interpretations in form of values ranging from 0-2 for all the above mentioned structures in three different methods were tabulated in Microsoft Excel sheet and subsequently taken into consideration to reach to conclusions.
**Fig. 1:** MIP (Maximum Intensity Projection) reconstructions, obtained from post-contrast T1 weighted sequence, in Sagittal plane(a), Coronal plane(b), axial plane(c) showing various venous structures included in study. (SSS- Superior Sagittal Sinus, ISS- Inferior Sagittal Sinus, VT- Trolard Vein, TSVs- Thalomostriate Veins, ICVs- Internal Cerebral Veins, VG- Vein of Galen, SS- Straight Sinus, BVRs- Basal Veins of Rosenthal, TH- Torcular Herophili, SGS(r,l)- Sigmoid Sinus(right, left), LS(r,l)- Lateral Sinus(right, left))

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Fig. 2: 180 degrees rotational reconstructions video in coronal & axial planes with angle between images of 10 degrees.

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Results

1. In broad terms, quite expectedly, CE-MRI method showed to gather more values in terms of the summation of all values for all study venous structures in all 10 patients, thereby, showing its diagnostic edge to visualize the structures over other 2 methods which are 2D TOF, and 3D PC. However, it remains a challenge to figure out the better method (between 2D TOF and 3D PC) in those clinical cases when contrast enhanced studies are not indicated or are not required to be done. Overall, considering all structures together, it would not be appropriate to pick one sequence/method and label it as better than the other, as both non-contrast MRV methods (2D TOF and 3D PC) have their own advantages and limitations when assessing different venous structures.

2. After comparison of data of 2 observers statistically (Two-Sample T-Test), it was concluded that 2 observations were not significantly different from each other. P-values were significantly > 0.025 in all three methods, thereby, excluding statistical difference between observations of 2 observers.

3. This study showed when all deep venous structures (ICVs, TSVs, BVRs, VG, SS, ISS) are taken into consideration, 3D PC sequence scores over 2D TOF thereby showing that 3D PC is better modality than 2D TOF for viewing structures in this group. However, when structures are considered individually then results differ only in cases of TSVs and just marginally in cases of BVRs where 3D PC failed to prove as better modality for their visualization than 2D TOF while other structures in the group agreed (Table 1).

4. When all sinuses considered together including Torcular Herophili (SSS, LS, SGS, TH) which are part of study, 2D TOF marginally scores over 3D PC sequence. However, it is appropriate to mention at this juncture that when Torcular Herophili is considered individually then it is 3D PC sequence which scores much better than 2D TOF sequence (Table 2). Moreover, our study revealed, on evaluation of transverse sinuses on all 3 sequences, that out of 10 patients 5 patients had right transverse sinus dominance with left transverse sinus hypoplasia. While 2 patients showed co-dominant transverse sinuses. And 3 patients revealed left transverse sinus dominance with right transverse sinus hypoplasia.

5. Among the superficial venous system, Trolard veins (VTs) included in study, are better appreciated on 2D TOF sequence than on 3D PC sequence as shown in Table 3 which is contrary to popular belief, with Trolard veins (VTs) agreeing to the finding.
Table 1: Deep Venous Group (ICVs(r,l)- Internal Cerebral Veins(right,left); TSVs(r,l)- Thalamostriate Veins(right,left); BVRs(r,l)- Basal Veins of Rosenthal(right,left); VG- Vein of Galen; SS- Straight Sinus; ISS- Inferior Sagittal Sinus); TOF- 2D Time-of-Flight; PC- 3D Phase Contrast; CE-MRI - Contrast Enhanced-Magnetic Resonance Imaging)

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Table 2: Sinuses (SSS- Superior Sagittal Sinus, LS- Lateral Sinus, SGS- Sigmoid Sinus, TH- Torcular Herophili, r- right, l- left); TOF- 2D Time-of-Flight, PC- 3D Phase Contrast, CE-MRI - Contrast Enhanced-Magnetic Resonance Imaging

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Table 3: Superficial Vein (VT- Vein of Trolard, r- right, l- left); TOF- 2D Time-of-Flight, PC- 3D Phase Contrast, CE-MRI - Contrast Enhanced-Magnetic Resonance Imaging

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Conclusion

1. Conclusively, it can be mentioned, that if in a patient post-contrast examination is indicated and intra-cranial venous system has to be assessed then it is not worth to carry out 2D TOF and 3D PC especially to assess venous system. In other conditions when use of contrast is not indicated then for deep venous group assessment 3D PC sequence is better than 2D TOF except for BVRs and TSVs. Additionally, for assessment of sinuses 2D TOF is better than 3D PC except in case of TH, for which 3D PC is far better than 2D TOF. Lastly, in case of Vein of Trolard (VT) 2D TOF is better modality.

Taking into consideration all the drawbacks and advantages of all methods, it is pertinent to mention, after our experience in this study that the routine Contrast-Enhanced MRI (T1 Weighted) when used with additional, that is to say, MIP (Maximum Intensity Projection) and rotational reconstructions it works as a useful and better modality than 2D TOF and 3D PC in the assessment of intra-cranial venous system, which maybe in the past literature has not been stressed upon.

2. Indeed, in our series, we found that the distribution of transverse sinus dominance was in excellent agreement with the distributions reported in the literature, which were based on conventional DSA (Digital Subtraction Angiography) (Figure 3). Flow gaps when observed in few cases were located either in hypoplastic side or area of Torcular Herophili. It should be noted that these flow gaps were apparent mostly on 2D TOF sequence and were not noticeable on 3D T1 post-contrast sequence (CE-MRI), except in couple of cases when it turned out to be arachnoid granulations after evaluation of corresponding T2 weighted sequence et al. These findings are in accordance with and support study done by Ayanzen et al[1]. In other cases, it could be believed that these transverse sinus flow gaps, which were found only in nondominant transverse sinuses, are artificial in nature as found in some patients in our study, as is supported by CE-MRI which shows hypoplastic nature of tranverse sinus being shown as flow gap on 2D TOF sequence (Figure 4).

3. In 3D PC, MIP and rotational reconstructions without additional post-processing, it is found that intra-cranial venous system assessment is difficult due to interference by presence of arterial system (Figure 5).
Fig. 3: A-C, Transverse sinuses were found to be right(A), left(B), and codominant(C) in 59%, 25%, and 16% of the cases examined, respectively.


Fig. 4: a. In 2D TOF image flow gap is seen in area of junction between Torcular Herophili & Left Lateral Sinus (shown in fig. by arrow). b. In 3D PC image no apparent flow gap visible. c. In Contrast Enhanced - MRI image no apparent flow gap visible which proves the presence of artificial character of flow gap seen on 2D TOF.

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**Fig. 5:** MIP (Maximum Intensity Projection) reconstructions from 3D Phase Contrast showing signals from arterial flow (shown by blue arrows) which interfere assessment of venous structures.

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References


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