Tentorial Venous Anatomy: Variation in the Normal Population
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The authors have no relevant disclosures
Background

Recently, we described a trans-tentorial venous system consisting of the medial, intermediate, and lateral tentorial veins, connecting infra- and supratentorial compartments in two cadaver dissections and two patient scans.

Based on this, we investigated tentorial venous anatomy in a larger normal population.
Methods

STUDY CRITERIA
Tentorial venous anatomy of the head was evaluated on MRI and MRA with and without contrast, CTA, and CTV which were performed as part of routine care or for research over one year at a single institution. We included 238 studies with adequate contrast opacification of the venous structures and slice thickness <2mm. Patients with known space-occupying lesions or vascular pathologies were excluded. The study protocol for retrospective chart review was approved by the institutional review board of the Johns Hopkins University Hospital.

RADIOLOGIC MEASURES
Bony measurements were performed on CT to assess skull base development. Parasagittal angle was measured as the angle between a mid-sagittal line from the nasal septum to the internal occipital protuberance and a second line on each side from the sphenoid-occipital synchondrosis to the stylomastoid foramen. The angle between the internal auditory canal and petroclival fissure (IAC-PCF angle) was also measured. The distance between the carotid canal and jugular bulb (CC-JB distance) was taken one slice before the turn of the petrous carotid. Development of the petrous apex was assessed by petrous apex pneumatization. Tentorial angle was measured as the angle between two lines: one extending from the nasion through the tuberculum sella and a second through the straight sinus in the mid-sagittal plane. The transverse sinuses were assessed for patency. The cavernous sinuses were similarly assessed for patency. The presence of a split confluens sinuum was also noted. The tentorial sinuses and veins were assessed.

VOLUMETRIC RECONSTRUCTION OF CT VENOGRAPHY
Volume rendered 3D images were generated using SkyScan CT-Vox software. DICOM study files were imported into CTVox in DICOM 8-bit format. The import histogram was restricted to exclude parenchyma and saturate bone and contrast. The opacity was adjusted to show a limited view of the surrounding soft tissues and highlight vessels with contrast.

STATISTICAL MEASURES
Predictors of tentorial venous anatomy were assessed via Cramér V association, binary encoded Pearson correlation, and Nearest-Point Algorithm with Euclidean distance metric for clustering.
Results: Representative Imaging

Figure 1. Trans-Tentorial Veins. All images shown are 3D volumetric reconstruction of delayed phase CTA of the head and neck; parenchyma has been segmented out, leaving the intracranial vessels filled with contrast. **Panel A:** The reconstructed volume of the head is shown from the anteroposterior view with a 30° downward rotation to show the plane of the tentorium. **Panel B:** The same reconstruction in panel A is rotated to show the left side. **Panel C:** The same reconstruction rotated to show the right side, which is symmetric. **Panels D-F:** Source axial images for the volumetric reconstruction of this scan are shown; ITV, MTV, and LTV are labeled. ICV, internal cerebral vein; VGC, Vein of Galen confluens; SS, straight sinus; SPS, superior petrosal sinus.
Results: Three Configurations of Tentorial Veins

Figure 2. Schematic Representation of Three Trans-Tentorial Vein Configurations. The two groups of tentorial sinus configurations are shown; group 1, which is subdivided, has a RC while group 2 does not. Regions of variation are shaded in purple; cross-hatching denotes sinuses and veins are colored in blue. Panel A: Configuration 1A has a medialized RC and the ITV is interrupted by plexiform anastomosis to the RC or LTS. Panel B: Configuration 1B has a lateralized RC and the ITV is uninterrupted. Panel C: In configuration 2, the RC is absent; the LTV connects the MTS to the LTS and the LTS to the superior petrosal sinus. Relevant draining sinuses are also shown. CS, Cavernous Sinus; ATV, Apical Tentorial Vein; CBV, Cerebellar Bridging Vein; ICS, Intercavernous Sinus; ISS, Inferior Sagittal Sinus; MBV, Mesencephalic Bridging Vein; PA, Plexiform Anastomosis; SpPS, Sphenoparietal Sinus; SS, Straight Sinus; SSS, Superior Sagittal Sinus; VGC, Vein of Galen Confluens; VG, Vein of Galen
Figure 3. Association and Correlation with Clustering Highlights Common Tentorial Vein Configurations. Left: Cramér’s V association heat-map, a symmetrical measure of association between categorical variables, presents two intercorrelated variable groupings. The first shows high to perfect association amongst MTS Origin, RC, ITV, and LTV. The second shows moderate to high association amongst Cavernous Sinus, LTS Origin, TS, and MTV. Right: Pearson Correlation heat-map reveals two primary configurations, one of which also has an alternate configuration, based on the presence or absence of the ringed connection of the MTS and LTS. In the first configuration, the RC is medialized. Due to the presence of the medialized RC originating from the MTS at the straight sinus, the tentorial veins have the following connections: the ITV is interrupted by the ringed configuration, and the LTV is lateralized, draining to the superior petrosal sinus. An alternate and slightly less common configuration was comprised of a lateralized RC and resultant medialized LTV. The second primary configuration has no RC; the ITV is interrupted by the LTS and the LTV is also interrupted by LTS. In this configuration, the MTS may be present or absent. IAC-PCF(L) and (R), degrees; Parasagittal Angle (L) and (R), degrees; CC-JB distance (L) and (R), millimeters; remaining variables are categorical. ITV was categorized as 0 through 4 as per results of preliminary categorization. LTV was categorized as 1 through 3 as per results of preliminary categorization.
Results: Predictors of Tentorial Venous Anatomy

Figure 4. Uncertainty Coefficient (Theil’s U) Heat-map for Bony Measurements, Dural Sinus categories, and Tentorial Vein categories. Theil’s U association heatmap, an asymmetrical measure of association between categorical variables, confirmed the two intercorrelated variable groupings. The uncertainty coefficient at a given row and column indicates what fraction of the column variable can be predicted given the row variable. It verifies the strong relationships amongst the first grouping (MTS Origin, RC, ITV, and LTV), as well as amongst the second grouping (Cavernous Sinus, LTS Origin, Transverse Sinus, and MTV).
Discussion

• This report demonstrates tentorial venous anatomy in a large normal population using CTA/CTV (n=238).
• Further, we identified bony measurements of the skull base as predictors of two primary groups of tentorial venous anatomy.
• These groups were correlated to the ringed configuration of the tentorial sinuses.
• Groups 1A, which was characterized by a medialized RC, and 1B, which was characterized by a lateralized RC, were correlated to the presence of a split confluens, a proposed sign of incomplete late development of the dural sinuses.
• Conversely, group 2 (characterized by the absence of the RC) was correlated with complete development of the confluens.
• Further, these groups were predicted by bony measures of skull base development, such as the degree of petrous apex pneumatization or IAC-PCF angle.
• The statistical analyses performed in this study not only allowed the confirmation of the presence of trans-tentorial venous system but also identified relationship between completed development of the skull base and the configurations of this venous drainage.
Summary

The analysis of 238 patients identified variations of the trans-tentorial venous system in a large normal population and identified bony measures of skull base development as predictors of three groups of this venous anatomy. Knowledge of this anatomy is critical for surgical planning and intervention and may help to explain surgical complications arising from compromise of the tentorial venous system.