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Background and Purpose—Literature is sparse on the frequency and significance of anatomical venous variants (AVVs) in pediatric cerebral sinovenous thrombosis (CSVT).

Methods—We retrospectively reviewed children with CSVT and controls undergoing computed tomography/magnetic resonance venography from January 2008 to 2014. Clinical features examined included raised intracranial pressure, risk factors, and treatment. Radiological features examined included CSVT location, presence and type of AVVs, hemorrhagic venous infarction, and venous collateralization. Clinical outcome was measured by the pediatric stroke outcome measure and radiological outcome by thrombus recanalization.

Results—Fifty-one children with CSVT were identified. Twenty-two (43%) had AVVs at presentation. Nineteen (86%) had hypoplasia/absence of major dural sinus, 5 (23%) had persistent fetal structures, 3 (14%) had duplications/fenestrations, and 1 (5%) had disconnected superficial and deep venous systems. Controls had a slightly higher but nonsignificant prevalence 26 (51%) of AVVs. No significant clinical and radiological differences were observed between children with CSVT and AVVs compared with those with typical venous anatomy.

Conclusions—AVVs are seen in many children with and without CSVT and do not seem to alter the presentation or clinical course. The influence of these variations on the brain's ability to tolerate venous congestion because of thrombosis merits further study. **(*Stroke*. 2019;50:178-180. DOI: 10.1161/STROKEAHA.118.023482.)**

Key Words: anatomy ■ cerebral veins ■ cerebrovascular disorders ■ pediatrics ■ thrombosis

Pediatric cerebral sinovenous thrombosis (CSVT) is a rare but serious neurological disorder with a reported incidence of 0.25 to 0.67/100 000 children per year[1] and 0.82 to 12/neonates per year.[1] Several studies have looked at predictors and long-term outcomes[2–4] of pediatric CSVT but few[5] have examined how variations in cerebral venous anatomy alter the physiology of cerebral venous blood flow and course of CSVT. Anatomical venous variants (AVVs) are routinely identified during computed tomography/magnetic resonance venography (CTV/MRV) in pediatric CSVT,[6] but there is sparse literature on their significance.[5,6] We hypothesized that (1) AVVs are more frequently encountered in children with CSVT than in those without CSVT and (2) AVVs can either impede flow and increase thrombosis risk or improve flow and make venous congestion tolerable. The objective of this study was to determine if there was a difference in the prevalence of normal venous anatomy and AVVs in children with and without CSVT and to assess indirectly if these variations influence intracranial venous physiology and outcome.

Methods

The authors declare that all supporting data are available within the article and its online-only Data Supplement. We retrospectively reviewed children (term neonates—18 years) with CSVT from January 2008 to 2014 through our institutional Stroke Program database. Institutional research ethics board approval was obtained. Informed consent was not required. Inclusion required a diagnosis of radiologically confirmed CSVT and at least 1 follow-up CTV/MRV. The study used a nonprobability sampling technique which included all CSVT patients seen from January 2008 to 2014 that met the inclusion criteria.[7] We excluded premature children and those with comorbid cerebral pathology (Figure I in the online-only Data Supplement). We collected clinical and radiological data including age at diagnosis, presenting symptoms, risk factors, thrombus location, parenchymal involvement, hemorrhagic venous infarction, antithrombotic regimen, acetazolamide therapy, clinical outcome, and recanalization at follow-up. Clinical symptoms and signs of increased intracranial pressure were defined as the presence of papilledema alone with/without sixth cranial nerve palsy or headache with altered level of consciousness.

Follow-up imaging was analyzed to determine thrombus propagation and recanalization. Propagation definition and recanalization grading were based on a previously published study.[2] Early recanalization was defined as partial/complete recanalization at first follow-up

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neuroimaging. Clinical outcome was determined at latest follow-up using the validated pediatric stroke outcome measure (PSOM).[8] Outcomes were dichotomized as good (PSOM ≤0.5) or poor (PSOM ≥1). Neurological comorbidity was an exclusion criterion and defined as any concurrent medical condition that contributed to a neurological deficit on the PSOM, which could not be accounted by CSVT alone.

Controls (term neonates—18 years without CSVT, who underwent CTV/MRV from 2008 to 2014) were identified through our institutional radiology database. Premature infants and those with comorbid conditions deemed to likely influence intracranial venous circulation (intracranial hemorrhage, vascular malformations, etc) were excluded. Controls were matched 1:1 to cases by age, sex, and cohort year.

Two pediatric stroke fellowship-trained reviewers (Drs Kouzmitcheva and Andrade), reviewed CTV/MRV for AVVs at presentation and follow-up and correlated findings to original neuroimaging reports. Disagreements were adjudicated by Dr Moharir. AVVs included, but were not limited to, hypoplastic/absent major dural sinuses; persistent fetal structures (occipital/falcine sinus); and others like variable anterior origin of superior sagittal sinus, disconnected superficial and deep venous systems, and sinus duplication or fenestration/septation (Figure). Venous collaterals were studied separately as surrogate markers of venous compensation.

Statistical Analysis

Conditional logistic regression for matched-pair data analysis was performed to compare the frequency of AVVs between cases and controls. Fisher exact test was used for the comparative exploratory analysis to assess characteristics and outcome of CSVT cases with variants compared with those without. A P value <0.05 was considered significant. Subgroup analysis was performed on children with prominent venous collaterals. Data analysis was performed by using SAS 9.4 software (SAS Institute Inc, Cary, NC).

Results

Fifty-one cases (28 males [55%], 13 neonates [25%], mean age at CSVT 5.9 years [0–17 years]) were identified (Table I in the online-only Data Supplement). Twenty-two (43%) had AVVs compared with 29 (57%) with typical anatomy. Nineteen (86%) had hypoplastic/absent major dural sinus, 5 (23%) had persistent fetal structures, 3 (14%) had sinus duplication/fenestration or septation, and 1 (5%) had disconnected deep and superficial venous systems. Most cases had >1 concurrent AVVs. Seven (14%) children had prominent venous collaterals; 3 (6%) of these were not associated with AVVs. Nearly all cases 49 (96%) received anticoagulants. Propagation occurred in 4 (8%) cases equally distributed between those with and without AVVs. Early recanalization occurred in 30 (59%). Median recanalization time was 3.5 (1.3–66.3) months.

Control subjects had a slightly higher prevalence of AVVs 26/51 (51%; Table). Common indications for CTV/MRV in controls were arterial stroke 17 (33%) and headache 11 (22%; Table II in the online-only Data Supplement). AVVs in controls included 21 (81%) with hypoplastic/absent major dural sinus; 3 (12%) with persistent fetal structures; 3 (12%) with sinus duplication/fenestration or septation; and 2 (8%) with disconnected deep and superficial venous systems (Table). There was no statistically significant difference in the frequency or type of AVVs between cases and controls (Table).

Features of raised intracranial pressure were seen equally in children with AVVs 7 (32%) compared with those without AVVs 10 (34%; Table III in the online-only Data Supplement). There were no statistically significant differences in the risk factors, acetazolamide therapy, or the presence of prominent venous collaterals between groups. Seven children (32%) with AVVs had parenchymal brain lesions compared with 8 (28%) with normal anatomy. There was no significant difference in hemorrhagic venous infarction 5 (23%) versus 4 (14%) and early recanalization rate 14 (64%) versus 16 (55%) as well.

Forty-four cases were included for final analysis (5 excluded because of significant association between PSOM and neurological comorbidity [P=0.0068]; 2 with missing PSOM). No significant differences were observed between the 2 groups with a median follow-up time of 7.3 (1.6–86.7) months.

We identified 7 (14%) children with prominent venous collaterals, of which 3 (6%) did not have other AVVs. There were no significant differences in outcomes between those with/without venous collaterals.

Discussion

We found no significant difference in type and frequency of AVVs between cases and controls (Table) and no significant

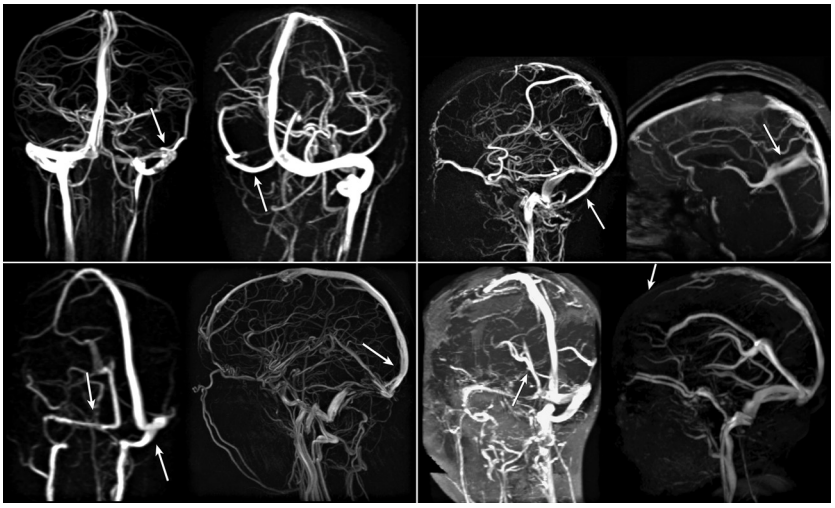

Figure. Selected examples of anatomical venous variants seen in the case-control cohort.

Table. Frequency of Intracranial Venous Variants Between Cases and Controls

Variation (X^2=0.7191, P Value=0.3964)	Cases 22/51 (43%)	Controls 26/51 (51%)
Hypoplasia/absence	19 (86%)	21 (81%)
Left TS hypoplastic	9 (41%)	16 (62%)
Right TS hypoplastic	8 (36%)	5 (19%)
Bilateral TS hypoplastic	1 (5%)	
Bilateral sigmoid sinus hypoplastic	1 (5%)	
Persistent fetal structures	5 (23%)	3 (12%)
Left occipital sinus	1 (5%)	2 (8%)
Right occipital sinus	2 (9%)	1 (4%)
Bilateral occipital sinuses	1 (5%)	
Falcine sinus	1 (5%)	
Duplication/fenestration/septation	3 (14%)	3 (12%)
Duplication/fenestration of SSS	1 (5%)	1 (4%)
Double-channel straight sinus	1 (5%)	1 (4%)
Vein of galen septation	1 (5%)	1 (4%)
Complex anatomy of torcula		
Disconnected superficial and deep systems	1 (5%)	2 (8%)

SSS indicates superior sagittal sinus; and TS, transverse sinus hypoplasia.

difference in clinical or radiological outcome in children with CSVT and AVVs compared with those with normal venous anatomy. Our initial hypothesis was that children with CSVT who have AVVs might have a worse clinical presentation, higher frequency of venous infarction, and worse outcome, as they lack proper compensatory mechanisms needed to establish adequate cerebral drainage when presented with physiological stress, such as obstruction because of thrombosis. It became apparent when the AVVs were categorized that our hypothesis needed to be refined as some AVVs could theoretically not only impede venous outflow but, on the contrary, improve venous outflow and not necessarily lead to adverse outcomes. We hypothesized that variants like hypoplasia/aplasia could impede flow because of inadequate capacity to drain blood and thereby increase venous congestion. This theory is supported by a recent study[5] showing that contralateral hypoplastic venous draining sinuses are associated with raised intracranial pressure when there is CSVT in the dominant side. Using the same rationale, we hypothesized that variants consisting of persistent fetal structures may improve flow by providing an alternate collateral pathway that ultimately reduces venous congestion. Less frequently encountered variants, such as duplications and fenestrations, in theory, could increase venous endothelial surface area thereby increasing the clot size and reducing the sinus caliber resulting in slow flow and clot propagation. Finally, complete disconnection between the superficial and deep venous systems provides no communication or collateral flow leading to impaired ability to maintain normal venous drainage. Over time, development of numerous collateral veins may support venous drainage by bypassing the occlusion, thus restoring cerebral hemodynamic status and facilitating recovery. We, therefore, presumed that collateralization in the presence of thrombosis might indicate a robust compensatory response and, therefore, a better outcome although our observations did not support this.

Our study has limitations as it was a single-center, retrospective study with a sample size that was not large enough to detect a difference between cases and controls. In addition, there was no direct way of knowing whether the variants, in fact, were contributing to improved or impaired redistribution of venous outflow except to study clinical and radiological correlations. It is not known how quickly and efficiently venous collateral channels open after occlusion. For this reason, this study is not able to ascertain the physiological effects contributed by AVVs directly but can only speculate on their possible mechanism. Furthermore, our controls were not healthy given the indications for CTV/MRV. This may have led to selection bias in our results by including children with idiopathic intracranial hypertension. Children with idiopathic intracranial hypertension can have neuroimaging findings of unilateral/bilateral transverse sinus stenosis, which could have potentially been unintentionally misread as hypoplastic variants.

In summary, our findings suggest that AVVs are prevalent in children with/without CSVT and their influence on the brain's ability to tolerate venous congestion merits further study.

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Disclosures

None.

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