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Venous Sinus Stenosis with Prominent Emissary Veins: A New Common Cranial MRI Finding of Mucopolysaccharidosis I

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ABSTRACT

SUMMARY: Mucopolysaccharidosis I-Hurler (MPSIH) syndrome is the most severe form of a group of hereditary lysosomal diseases. This study aims to describe previously unreported common cranial findings of sigmoid sinus stenosis with prominent emissary veins in MPSIH. A retrospective review was conducted of 66 patients with MPSIH who were treated at our institution. A total of 12 cranial MR imaging studies from 12 different patients demonstrating the venous sinus anatomy were reviewed. All 12 patients exhibited various degrees of sigmoid or transverse sinus stenosis. Eleven had various forms of emissary veins. Of those 12 patients with imaging of the venous sinuses, 9 had a lumbar puncture within the same months as the acquisition of the venogram without any correlation between elevated opening pressure and the severity of the venous sinus stenosis. Stenotic cerebral venous sinuses with associated emissary veins, common in patients with MPSIH, may be abnormal findings due to posterior fossa horns from glycosaminoglycan depositions rather than signs of elevated intracranial pressure or requirement of CSF diversion.

ABBREVIATIONS: GAG = glycosaminoglycan; HSCT = hematopoietic stem cell transplant; MPSIH = mucopolysaccharidosis I-Hurler; OP = opening pressure; VP = ventriculoperitoneal

Mucopolysaccharidosis type I, Hurler (MPSIH) syndrome is a severe, rare genetic lysosomal storage disease characterized by the accumulation of glycosaminoglycan (GAG) within the lysosomes due to α-L-iduronidase deficiency. Elevated GAG levels can be found in many tissues and body fluids, leading to progressive organ damage, cardiovascular complications, neurocognitive delay, and skeletal abnormalities.[1]

The brain and cranial imaging manifestations of MPSIH have been well-studied and include WM signal-intensity abnormality, ventricular dilation, hydrocephalus, enlarged perivascular spaces, a J-shaped sella turcica, an enlarged pituitary gland, and posterior fossa horns (hypertrophy of the occipitomastoid sutures).[2-5] Hydrocephalus is an early manifestation in patients with MPSIH, and prompt recognition and treatment can potentially prevent neurocognitive decline or even mortality.[4,6] One common hypothesis is that skull abnormalities could lead to venous hypertension, which contributes to hydrocephalus in MPSIH. However, to our knowledge, no studies have evaluated the venous anatomy in patients with MPSIH or its correlation with intracranial pressure.[7,8] Studies in idiopathic intracranial hypertension (pseudotumor cerebri) have described the role of posterior fossa emissary veins as collateral venous outlets in transverse sinus stenosis that help to prevent or lessen intracranial pressures.[9,10] In this study, we describe the high prevalence of posterior fossa horns, venous sinus stenosis, and prominent emissary veins in patients with MPSIH and examine their possible correlation with intracranial pressure.

MATERIALS AND METHODS

A total of 66 patients with MPSIH treated with hematopoietic stem cell transplant (HSCT) at our institution between 2008 and 2020 were retrospectively reviewed. Of those patients, 8 patients had dedicated MRVs and another 4 had high-resolution, contrast-enhanced 3D T1-weighted MPRAGE images with sufficient detail to allow evaluation of the venous sinuses. The venograms were obtained in accordance with our institution's existing stem cell transplant protocol. The contrast-enhanced MR images were obtained to assess infection, ophthalmologic pathology, and hormonal deficiencies. The radiologic assessments were performed by a resident and confirmed by an attending neuroradiologist for posterior fossa horns, venous stenosis, and emissary veins. Charts of the 12 patients were reviewed for concurrent CSF opening pressure (OP) measurements within 30 days of MR imaging. Lumbar punctures were performed with the patient in the lateral

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decubitus position with maintained end-tidal CO_2 of 25-40 mm Hg.[11] Whether ventriculoperitoneal (VP) shunts were present was also assessed. Ten children without MPSIH who underwent MRV in 2020 were reviewed and included as a control population. This study was performed in accordance with the rules and regulations of Committee on the Use of Human Subjects in Research at the University of Minnesota (IRB STUDY00010613).

RESULTS

All 12 patients with sufficient imaging demonstrated some degree of venous sinus stenosis and posterior fossa horns, with an average age of 3.1 years at the time of the MRV (Online Supplemental Data). Eleven of the 12 patients had emissary veins or venous plexuses draining from either the sigmoid sinus, torcula, superior sagittal sinus, or jugular bulb (Fig 1). Nine of the 12 patients had an OP measured with a mean of 24 cm H_2O (range, 7–37 cm H_2O). Three of those 9 patients had an OP of >28 cm H_2O. Two of the 12 patients had a VP shunt placed 4 years after HSCT due to the discovery of a papilledema refractory to medical therapy but with normal OP and ventricular size, and their contrast-enhancing MR images were obtained 5 years after VP shunt placement to assess a hormonal deficiency (9 years after HSCT). On the basis of MR imaging, 1 patient was found to have acute hydrocephalus 22 days after HSCT, for which a VP shunt was eventually placed, and this patient's MRV was obtained before HSCT as part of the pretransplantation work-up. The average age at the time of MRV was 2.1 years for the 10 controls. Three of them underwent MRV for a work-up of intracerebral hemorrhage; 2, for seizure work-up; 2, for visual disturbance work-up; and 3, for surveillance of known vascular abnormalities (Online Supplemental Data). None of the patients in the control group had intracranial hypertension or shunts. Only 2 had some degree of posterior fossa horns, and only 1 had emissary veins (Fig 2).

DISCUSSION

MPSIH is associated with varying degrees of CNS involvement and a resultant impact on neurodevelopment. Previous studies have summarized various types of CNS pathology, including WM signal-intensity abnormality, ventricular dilation, hydrocephalus, enlarged perivascular spaces, a J-shaped sella turcica, an enlarged pituitary, and recently described posterior fossa horns (hypertrophy of the occipitomastoid sutures).[2-5,7] Several case reports have reported large occipital emissary veins in healthy cohorts, and the presence of emissary veins potentially improves cerebellar venous outflow and thus prevents the increase in intracranial hypertension.[7,8] To our knowledge, prominent emissary veins in MPSIH have not been reported in the literature. Recently in the literature, a high prevalence posterior fossa horns due to internal hypertrophy of the occipitomastoid sutures and the subsequent regression of posterior fossa horns have been described in MPSIH.[3,4,12] We propose a possible interaction between the posterior fossa horns, the impaired venous outflow, and intracranial hypertension. More specifically, the prominent posterior fossa horns, which develop possibly due to GAG deposits, just inferior to the transverse sinuses and posterior to the sigmoid sinuses narrow the posterior fossa. The posterior fossa horns compress the cerebellar hemispheres, which, in turn, compress the sigmoid and transverse sinuses, resulting in venous hypertension and poor CSF resorption.

In adult patients with idiopathic intracranial hypertension, various degrees of venous sinus stenosis are seen, and alleviation of intracranial hypertension via venous sinus stent placement in those patients supports the hypothesis that elevation in venous pressure restricts CSF resorption.[13] Furthermore in those patients, alternative cerebral venous drainage has been reported, and occipital emissary veins and extrajugular venous drainage have been described as hallmarks of idiopathic intracranial hypertension.[9,10,14,15] We, therefore, postulated that the compression of the sigmoid and transverse sinuses drives the development or enlargement of emissary veins in patients with MPSIH to provide alternative venous outflow, alleviate the venous hypertension, and ultimately improve CSF resorption and decrease the likelihood of developing hydrocephalus.

Although the exact incidence of hydrocephalus in MPSIH is unclear, 1 large multicenter study reported 30.6% of patients with hydrocephalus before HSCT and 5.9% with persistent hydrocephalus after HSCT.[11,16,17] In our study of 12 patients, we discovered that 3 of the 12 patients had VP shunt placement. All 12 patients had some degree of venous stenosis and posterior fossa horns compared with only 2 patients with posterior fossa horns and 1 patient with bilateral emissary veins in the control group. Almost all of them (11 of the 12) had prominent emissary veins from the sigmoid sinus or torcula. The mean OP among 9 of the 12 patients was 24 cm H_2O, which was the reported average OP in 25 patients with MPSIH in a previous study.[11] Only 3 of those 9 patients had an OP of >28 H_2O cm, which is the recently established upper normal limit of OP in the pediatric population.[18] In our study of 12 patients, at the same time that the venogram was obtained, all 3 patients with elevated OP had

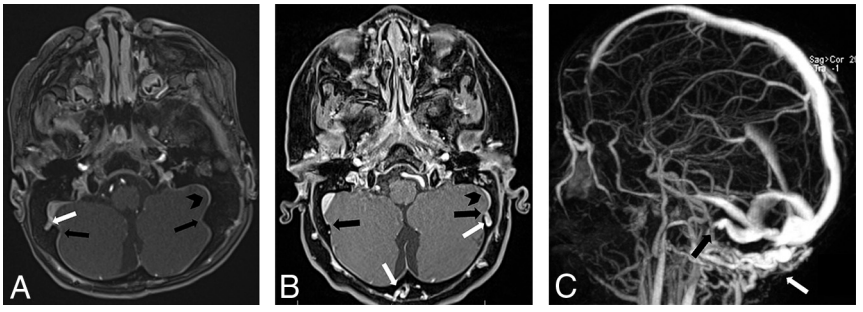

FIG 1. *A*, Axial T1-weighted image with contrast (patient 3) demonstrates prominent bilateral posterior fossa horns (*black arrows*) with a draining emissary vein from the right sigmoid sinus (*white arrow*) and a stenotic left sigmoid sinus (*black arrowhead*). *B*, Axial T1-weighted images with contrast (patient 10) demonstrate left-greater-than-right bilateral posterior fossa horns (*black arrows*) with a draining emissary vein from the left sigmoid sinus (*white arrow*), an emissary venous plexus (*white arrow*), and a stenotic left sigmoid sinus (*black arrowhead*). *C*, MRV (patient 8) shows a hypoplastic right transverse sinus (*black arrow*) with a large emissary venous plexus from the distal jugular bulb (*white arrow*).

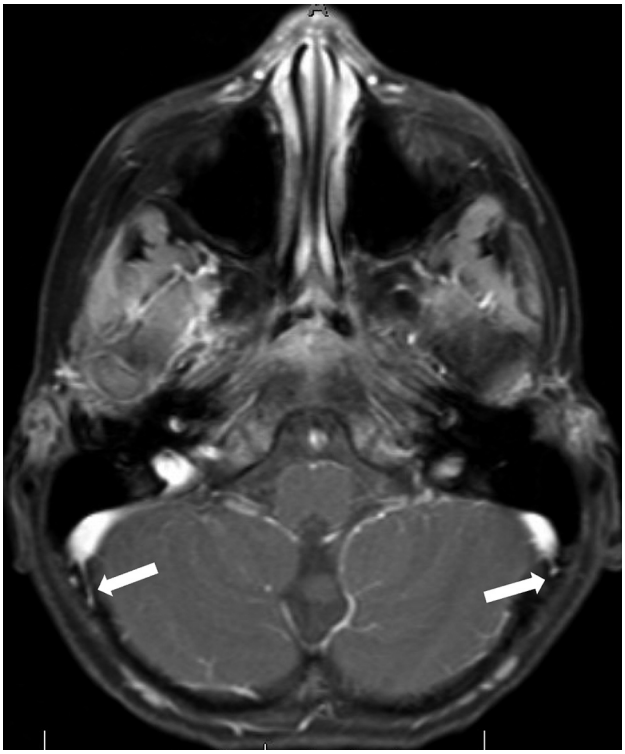

FIG 2. Axial T1-weighted image with contrast of patient 10 in the control population demonstrates small draining emissary veins from the bilateral sigmoid sinuses (*white arrows*).

venous stenosis and emissary veins, but none of them ultimately required shunt placement. Three of the 12 had VP shunts placed. One of the 3 patients developed acute ventriculomegaly and hydrocephalus on MR imaging 22 days after HSCT and required VP shunt placement, so the patient did not have OP measured and the patient's MRV was obtained as part of the pretransplantation evaluation. The other 2 patients with VP shunt placement had undergone the procedure 4 years after HSCT due medical refractory papilledema with normal OP, and their MR images were obtained 5 years after shunt placement for evaluation of hormonal deficiency. There was no apparent association of elevated OP or the incidence of VP shunting with the severity of posterior fossa horns or the degree of venous sinus stenosis. Emissary veins are equally prevalent, but they are found in patients with MPSIH with both normal and elevated OP, contrary to the patient group of similar ages that did not have MPSIH. Only one of them had bilateral emissary veins without venous sinus stenosis. The authors postulated that the various venous stenoses and subsequent development of emissary veins, in fact, might be a common finding in patients with MPSIH.

The retrospective nature of this study and the small size are 2 main limitations. Not all patients had a dedicated venogram, and not all patients had OP measurements. Several patients had venography and OP measurements at different stages of their treatment, ie, some of the studies were performed before HSCT and some were performed after HSCT. Multiple studies have reviewed the effects of HSCT in patients with MPSIH and found improvement in the incidence of hydrocephalus, possibly due to improvement in GAG deposits and CSF flow.[17,19] Therefore, the OP may be affected by the intrinsic characteristics of the CSF and is not a surrogate for venous hypertension. However, our study illustrated the high prevalence of venous stenosis and emissary veins, which was not previously described. Whether posterior fossa horns or venous sinus stenosis contributes to the development of hydrocephalus in MPSIH requires further investigation with a larger cohort.

CONCLUSIONS

Venous hypertension has long been postulated as one of the causes of hydrocephalus in patients with MPSIH. Adult studies in idiopathic intracranial hypertension have postulated that increased venous congestion leads to increased intracranial pressure. This study demonstrates that a similar mechanism may occur in patients with MPSIH. The posterior fossa horns likely cause venous sinus compression which, in turn, drives the development of compensatory collateral venous outflow, ie, emissary veins. However, given the high prevalence of venous emissary veins but the low incidence of a shunt, larger studies are needed to further characterize these features and hopefully help identify the patients who will develop hydrocephalus and guide the timing of CSF diversion.

Disclosure forms provided by the authors are available with the full text and PDF of this article at www.ajnr.org.

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