Mucopolysaccharidoses are diseases in which defects occur in the storage of polysaccharides within the lysosomes due to the absence of specific enzymes. Mucopolysaccharidosis Type VI, or Maroteaux-Lamy syndrome, is characterized by a deficiency of the enzyme arylsulfatase B (ASB). In patients with this disorder, craniocervical compression, carpal tunnel syndrome, and communicating hydrocephalus are common. Traditionally, hydrocephalus occurring in patients with MPS VI has been treated with shunt placements. Considering obstruction of the outlets from the fourth ventricle at the cranio-cervical transition, the authors decided to treat a female patient with MPS VI via endoscopic third ventriculostomy. She was 12 years old and had refractory headaches. This seems to be the first reported instance of the neuroendoscopic treatment of hydrocephalus in a patient with MPS VI. The pathophysiology is briefly discussed.

Case Report

History and Examination. A 12-year-old patient monitored by a local genetics service was referred for neurosurgical evaluation. A diagnosis of MPS VI was made according to the typical clinical findings associated with urine GAG levels of 320 μg/mg creatinine (reference: 26–97 μg/mg). The leukocytic activity of ASB was 8 nmol/hr/mg protein, confirming the disease.

In the previous 18 months, the patient had complained of headaches that were not relieved by common painkillers. In the months prior to the diagnosis of MPS VI, the headaches were associated with vomiting and worsened with physical activity. The patient had attended school regularly and was a good student prior to the onset of symptoms. The patient was regularly receiving Naglazyme (galsulfase) as enzyme replacement therapy.

Physical examination showed signs of macrocrania

This article contains some figures that are displayed in color online but in black-and-white in the print edition.
and the typical facial appearance associated with MPS VI. Muscle strength, sensitivity, and reflexes remained unchanged. Funduscopy revealed an edema of the papilla. Magnetic resonance imaging showed moderate ventricle dilation associated with periventricular hypersignal in T2, suggesting transependymal edema. An obstruction of the outlets from the fourth ventricle was noted in the craniocervical transition, which was associated with spinal cord compression close to the foramen magnum (Fig. 1). Given the refractoriness of symptoms to conservative treatment and the hydrocephalus, we opted for surgery.

**Operation.** A third ventriculostomy was performed using a Fogarty 4-Fr catheter through a minor right frontal bur hole. The procedure was conducted with the patient under general anesthesia and orotracheal intubation without the need for fibroscopy. Thickening of the floor of the third ventricle and arachnoid of the prepontine cistern was noted (Fig. 2).

**Postoperative Course.** The patient was discharged from the hospital 3 days after surgery with no complications. Dramatic reductions in symptoms were noted at the follow-up. The patient had returned to a high level of academic performance despite postoperative neuropsychological tests confirming recent memory loss, which was attributed to the delay in treating the hydrocephalus. An MRI study performed 6 months postprocedure showed discreet reductions in ventricle dimensions; however, clear radiological improvement in craniocervical transition (Fig. 3) was noted.

**Discussion**

Since first described in 1963, the diagnosis of MPS VI has been refined and is now based on clinical presentation and supplementary biochemical tests. An affected patient may present with slow growth, coarse facial characteristics, bone deformity, frequent infections of the upper airways, increased liver and spleen size, hearing loss, joint stiffness, and dry and brittle hair. High levels of urine GAGs indicate the existence of an MPS disease but do not provide a specific diagnosis. High levels of dermatan sulfate, detected by fine-layer chromatography or electrophoresis, as well as ASB activity < 10% of the lower limit in isolated leukocytes or fibroblasts cultivated in the laboratory, can confirm the diagnosis of MPS VI.

Hydrocephalus, myelopathy, and compressive neuropathy are the most common disorders of the nervous system in MPS VI. The presence of these complications may necessitate surgical intervention.
system in patients with MPS VI.\textsuperscript{5,13} The presence of hydrocephalus is also well known in other MPS diseases,\textsuperscript{1} the causes of which are still debated. Some hypothesize that the disorder is caused by the deposit of GAGs and the infiltration of PAS-positive leukocytes into the arachnoid villi.\textsuperscript{1,15} Relatedly, infiltration of the meninges occurs, causing brain fluid absorption problems and leading to what is known as communicating hydrocephalus. As a result there is an accumulation of CSF and a progressive increase in ventricle dimensions.\textsuperscript{1}

The same leptomeningeal thickening that hinders CSF absorption causes the other neurological component of the disease in the craniocervical transition, which is spinal cord compression. Evidence suggests that there may be a limit on brain fluid outlets from the ventricle system, which are the foramina of Luschka and Magendie in the fourth ventricle.\textsuperscript{1} This limit causes an obstructive component in the pathophysiology of the hydrocephalus in patients with MPS VI, substantiating the use of endoscopy techniques to increase brain fluid release.\textsuperscript{11}

In terms of symptoms, vomiting, behavioral and visual disorders, and intracranial hypertension can occur, which is associated with headaches that may not respond to conservative treatment.\textsuperscript{1,13} In radiological terms, the best examination for determining intracranial hypertension is an MRI study. Magnetic resonance imaging provides great detail of the ventricle dimensions and their association with transependymal edema, as viewed in T2-weighted sequences. Changes in the white matter, although uncommon in MPS VI, can be associated with deposits of GAG and not solely the associated transependymal edema. In these cases, the use of spectroscopy as a coadjuvant may be useful, as previously applied in Hunter disease (MPS II).\textsuperscript{15}

Symptoms of eye sight impairment, such as blurring, or loss of eyesight may be associated with the advancement of hydrocephalus. Although the disease typically manifests with corneal opacification and more rarely compression of the sheath of the optic nerve due to dural thickening, it is prudent to evaluate the brain using tomography or MRI to determine if hydrocephalus is present. The presence of papilledema, as reported in the present case, may occur in children with MPS VI and is not necessarily associated with intracranial hypertension.\textsuperscript{10}

Additional tests such as lumbar puncture and the measurement of brain fluid pressure (> 20 cm H\textsubscript{2}O) have been adopted when diagnosing hydrocephalus in patients with MPS.\textsuperscript{1} When confirmed by clinical and imaging tests, hydrocephalus in patients with MPS VI must be treated. Traditionally, ventriculoperitoneal shunt placement was indicated as a method of treatment, bearing in mind that the problem of hydrocephalus in these patients is merely based on absorption.\textsuperscript{1} The use of shunts carries the risk of infectious and obstructive (mechanical) complications that may lead to the cognitive deterioration of patients with MPS VI who would otherwise have good intellectual performance.\textsuperscript{2}

Third ventriculostomy was first described in 1923 by Mixter, who used a urethroscope.\textsuperscript{1} Rare complications can occur, such as lesions of the basilar artery, a brain fluid fistula, lesions of the fornix, and paresis of the third cranial nerve.\textsuperscript{3,4,7} No important technical problems were faced in the case presented. Although the floor of the third ventricle was thick, communication with the pre-pontine cistern was readily achieved with a Fogarty 4-Fr catheter. This thickening was also encountered in the arachnoid below the floor—Liliequist membrane—and may be a pathological finding of the disease.

The indication for neuroendoscopy procedures for extraventricular obstructions has recently been reported in the literature.\textsuperscript{1} Cases of normal-pressure hydrocephalus and Chiari malformation Type I are examples.\textsuperscript{11} In patients with myelopathy and syringomyelia associated with Chiari disease, there have been reports of clinical and radiological improvement of symptoms caused by the craniocervical compression after endoscopic third ventriculostomy.\textsuperscript{5,8,9,11}

Although one successful procedure does not permit ultimate conclusions, neuroendoscopic treatment of patients with MPS VI and hydrocephalus appears to be promising. Cases with different pathophysiological components, as was shown above, should reinforce correlations that may occur between the progression of spinal cord symptoms and the resolution of hydrocephalus.

Disclosure

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

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