Editorial

Cerebrospinal Fluid Dynamics Following Ventriculoperitoneal Shunt in Hydrocephalus: Do Technological Advancements Avoid Complications?

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Despite a relatively high risk of complication and failure, ventriculoperitoneal shunting (VPS) is the most common approach to surgically treat chronic hydrocephalus [1,2]. Although hydrocephalic patient mortality has been significantly reduced by introducing ventricular shunt systems, a wide variety of mid and long-term complications principally related to valve-regulated shunts are encountered and these underscore the complex pathophysiology of this condition [3,4].

Shunt malfunctions have been classified into three groups: (1) Mechanical failure related to improper functioning of the device, including obstructions, ruptures, migrations, and disconnection; (2) Infections related to colonization of implanted materials and development of clinical infection either of the CSF inside the shunt or the soft tissue around it; and (3) Functional issues related to the hydrodynamic properties of the shunt [5].

We have evaluated the long-term results of shunt therapy in patients with idiopathic normal pressure hydrocephalus (iNPH) with a follow-up period spanning ten years [1], this represents the most extended follow-up study conducted to date in the literature. We showed that VPS is a safe modality capable of improving symptoms in most patients, including long-term symptom management. Compared with other symptoms, gait disturbance showed sustained improvement following shunting, VPS displays a low complication rate, and this approach has met with long-term therapeutic success over for >70% of patients. In a ten-year follow-up study involving 14,455 patients who underwent VPS, the cumulative complication rate at five years was 32% and obstructive hydrocephalus was found to increase the risk of shunt complications [6]. Due to this high complication rate, other surgical approaches, based not on flow diversion, but tailored to re-establish physiologic CSF dynamics [7–9] have been proposed. For instance, in cases of hydrocephalus following aneurysmal subarachnoid hemorrhage, lamina terminalis fenestration (LTF) allows the removal of blood components from the subarachnoid space and reduces paravascular pressure, thus decreasing post-hemorrhagic obstruction and brain swelling [10–12]. However, the efficacy of LTF for decreasing shunt-dependency requires further investigation since fibrotic degeneration of arachnoid granulations is not prevented using this approach [13,14].

Shunt overdrainage is a common complication following VPS. This was first reported by Dandy in 1932 where an account of sudden drainage of cerebrospinal fluid (CSF) after surgery lead to intracranial hypotension with ventricular collapse [15] was detailed. In 1982, Hyde-Rowan *et al.* [16] described this condition, termed slit ventricle syndrome, that is characterized by intermittent headache (from 10 to 90 min), small ventricles on imaging studies, and slow filling of the valve reservoir on palpation due to the postural changes of CSF drainage. To date, shunt overdrainage is associated with severe headaches that interfere with activities of daily living in patients with CSF diversion systems and those with smaller or normal cerebral ventricles [17].

Pathophysiology of shunt overdrainage and slit ventricle syndrome has not been completely established and several theories are actively under investigation including acquired craniocerebral disproportion [18], periventricular gliosis [19], capillary absorption laziness [20], and pulsatile vector theory [21]. Moreover, the siphon effect is primarily associated with CSF overdrainage. In the supine position, the intracranial pressure is equivalent to that of the subarachnoid spinal space, however in the standing position, intracranial pressure falls to 0 mm H_2O (or to negative pressures) and increases up to 500 ± 50 mm H_2O at the lumbar level. Assuming the cranial-abdominal distance as approximately 50 cm, when patients go from lying down to standing, a gravity gradient forms between the ventricles and peritoneal cavity that is equivalent to the weight of the column of CSF inside the system (i.e., hydrostatic pressure) that is dependent on the height or distance between both cavities [22]. Consequently, a hydrostatic suction force (of up to -500 mm H_2O in this case) due to a siphon effect can easily exceed the valve's opening pressure even when the ventricular pressure is zero or negative. This results in shunt overdrainage and consequential ventricular collapse. Therefore, this theory prompts treatment of overdrainage by mitigating the siphon effect using anti-siphon devices or other systems that increase the resistance to drainage across the valve [15,23].

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Panagopoulos D *et al*. [24] conducted a narrative literature review focused on an analysis of shunt overdrainage and slit ventricle syndrome. The authors also reported technological advancements aimed in counteracting these treatment side effects. Moreover, they described CSF hydrodynamics in patients who undergo CSF flow diversion and reported evidence supporting a role for internal jugular vein collapse as a result of a moderate decrease of intracranial pressure when patients adopt a vertical position. Further, this report described the most relevant clinical and radiological criteria associated with slit ventricle syndrome, specifically, the most accepted pattern of overdrainage stemming from negative pressure, an on-off symptom complex, recurring proximal ventricular dysfunction, chronic subdural collections due to shunt overdrainage, and headaches unrelated to shunt function.

Overall, this study sought to clarify a complex and poorly understood condition which often influences patient prognosis. The authors are to be commended for bringing these issues to light as additional tailored preclinical and clinical studies are necessary to provide a set of best management principles for hydrocephalus-affected patients.

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