Overdrainage of cerebrospinal fluid and hydrocephalus shunts

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Normal pressure hydrocephalus (NPH) in adults is an only known form of reversible dementia. Remedy is quite simple: insertion of a hydrocephalus shunt (or third ventriculostomy, however less common in NPH). Shunts are supposed to drain excess of cerebrospinal fluid (CSF) from the brain, preventing three possible detrimental phenomena:

CSF accumulation, which may enlarge fluid pools and deform neural tracts around them

Possible CSF inflow into areas where it may provoke observed neurological deficit (like sinking of CSF into brain parenchyma and disturbing blood microcirculationin white matter around ventricles [3])

Building up dynamical excessive rises of intracranial pressure (ICP) [4]

After implantation of the shunt, CSF drainage is not always adequate. Both underdrainage (due to partial obstruction of fluid flow along inlet, shunt body or outlet) and overdrainage are not desirable. Overdrainage may cause persistent low-pressure headaches, subdural collections, collapse of ventricles, bleeding or, in case of lumbo-peritoneal shunt, down-side shifts of brain structures, including herniations. There are three types of overdrainage: related to body posture, related to excessive vasogenic pressure waves and related to excessive pumping of shunt prechamber (less common, but worth considering, particularly in paediatric cases).

Generally, posture related overdrainage is derived from the fact that in most of shunts flow is controlled by the differential pressure between inlet and outlet. Distance between ventricles and peritoneal space may produce in vertical body position additional pressure gradients. In ventriculo-peritoneal shunts this gradient generates distal negative pressure caused by the fluid column in peritoneal drain. In lumbo-peritoneal shunts this will be proximal positive pressure exerted by CSF column ranging from ventricles to lumbar catheter.

Body posture overdrainage is in depth evaluated in a recent superb study [2]. Three, popular overdrainage preventing devices and their hydrodynamic functionality are compared in elaborated hydrodynamic model:

Shunt Assistant increases shunt opening pressure in upright position. It should be placed and fixed (to prevent rotations after implantation) along body axis.

Membrane Device closes drainage pathway when pressure in distal tubing becomes less than atmospheric pressure transmitted to membrane through the skin. Unfortunately, the transmission may not be ideal in a presence of scars or fibrous tissue. It is worthwhile to mention that these devices are ineffective with lumboperitoneal shunts.

Siphon Guard is a classical flow regulator adding a large resistance if flow increases above certain threshold. This is a clever device, with one potential problem: after switching to the high-resistance state, it may never switchback to low resistance (this happens when differential pressure goes back to zero or negative values), which may contribute to intracranial hypertension [1].

It is worthwhile to add that Orbis-Sigma flow-controlling shunt is a valve and siphon preventing device in one. Unfortunately Orbis-Sigma offers only a single level of flow regulation. Nobody thought that this splendid construction requires adjustability like contemporary adjustable pressuredifferential valves.

Overdrainage related to ICP slow vasogenic waves (including effects secondary to deep breathing—particularly often seen in pleural placement of distal tubing) may lead to building up a negative ICP, irrespective to body position. Gravitational Shunt Assistant and Membrane Devices are not effective in such cases—like in overdrainage secondary to pumping shunt pre-chamber. Siphon Guard (or Orbis-Sigma valve) may help. We think that future shunts will not be passive devices but active, adjustable, electrically driven pumps. If they allow constant flow, regardless of input-output pressure gradient,CSF overdrainage will disappear for good.

References

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