Antisiphon device

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The development of the valve-regulated shunt in the 1950s led to the first opportunity for those born with neonatal hydrocephalus to survive with the potential for a reasonable cognitive and neurological outcome. With this major advance came a burden related to dependence on an implanted device that has taken decades to realize. Neurosurgeons are now seeing middle-aged patients who have received shunts in infancy. A self-reporting database managed by the Hydrocephalus Association reveals that 74% of patients from 20 to 45 years of age originally received shunts in the first 18 months of life.

Hydrocephalus is among the most chronic of human afflictions. In infancy it is a particularly cruel condition because of the effect of both the disease and its treatment on the quality of life throughout a patient’s life. Shunts lower intracranial pressure (ICP) and save lives. With the possible exception of very new technological advances, shunts have not normalized ICP dynamics. Infants with shunts experience chronic abnormalities of the skull and brain. The older child or adult who received a shunt in infancy will have a markedly thickened skull and generally has ventricles that are smaller than normal.

Gruber and Roehrig report on a very long follow-up study of patients treated with the Integra Neurosciences antisiphon device (ASD) in 2 groups of patients. In 1 group all patients who required a revision underwent placement of an ASD as part of the shunt. In a second group all newborns and premature newborns treated for hydrocephalus received a shunt system containing a differential pressure valve and an ASD as the first shunt. The follow-up of these patients averaged 10 years, and the results in terms of complications of treatment were compared with a historical control group. That historical control group represented the history of complications of shunt surgery prior to receiving an ASD. The use of historical controls is always problematic in terms of assessing the outcomes of any study. It is particularly troublesome in this case for 2 very important reasons. The first is that the patients in the control group presented with symptomatic shunt complications and not hydrocephalus. Patients who had undergone the treatment of hydrocephalus and who had no therapeutic complications would not show up in this analysis; therefore the complication rate in this group would, of necessity, be higher. The use of this group for historical controls also ignores the fact that a significant number of patients who received shunts in infancy may not remain dependent on their shunts. This possibility is most frequently encountered in posthemorrhagic hydrocephalus of the premature neonate. Patients not dependent on their shunts would not show up in the historical controls, and this would make for a higher complication rate for the control group.

The second problem with the use of historical controls, particularly in this study, relates to the era in which the change occurred. An abrupt change occurred in the practice of this center in 1978. It should be remembered that contemporary imaging studies such as CT scanning were not available until about 1973 and were not routinely used until sometime thereafter because of the costs and availability of scanners. A large percentage of the control group received shunts prior to the routine use of modern imaging, and this factor could also play a role.

While the conclusions of the study must be viewed in light of the problem of an appropriate control group, the take-home message of the work is still compelling. That message is that it is important to normalize the ICP dynamics in patients with hydrocephalus as early as possible in an attempt to avoid the long-term complications of shunt dependency. The routine use of devices that retard siphoning or prevent overdrainage will tend to normalize the ICPs regardless of the position of the patient. The ASD whose use is described in their article is the first device that was effective in preventing the extreme negativity of ICP when the patient goes from a recumbent to an erect position. Healthy patients without shunts will have an ICP of 10 mm Hg or 140 mm H2O when lying down. When they sit or stand up the pressure decreases to about −3 mm Hg. Patients with differential pressure valves that have no device to retard siphoning the usual erect pressure can be as low as −25 mm Hg, often resulting in headaches similar to spinal headaches. The ASD described here prevents overdrainage by the use of a diaphragm placed in line with the shunt valve system. It is essential that the device is placed under freely moving skin so that the diaphragm can be affected by changes in the internal pressure of the fluid in the shunt to atmospheric pressure. When the pressure in the shunt becomes negative with respect to atmospheric pressure, the diaphragm closes and stops flow through the shunt until ICP again becomes positive. The use of this add-on device as a replacement for a previous shunt requires that the device is not covered by a scar, as this will tend to interfere with the function of the diaphragm.

See the corresponding article in this issue, pp 4–16.
The routine use of shunt systems, which tend to normalize ICP dynamics for all patients with hydrocephalus, is an important concept and should be embraced by all neurosurgeons. The discussion portion of the study deals with the use of strategies to prevent overdrainage when the cause of that overdrainage relates to the hydrostatic forces involved in changes in positioning. Diaphragm mechanisms and gravity compensation are 2 of these strategies. The routine use of flow restriction, such as that exhibited by the OSV valve (Integra Neurosciences) or the add-on Siphonguard (Codman Corp.), is also an effective strategy in preventing subnormal ICP in individuals with shunts. The shunt design trial—a multicenter trial of 3 different shunt designs—failed to show an advantage for valves that prevented overdrainage.2,5 The problem with that study is that the average age of a patient receiving the first shunt was 4 months. This group was therefore somewhat comparable to the group of patients initially treated with the ASD in the Gruber and Roehrig study.3 Since infants have distensible skulls and growing brains the abnormalities seen in older patients may not be seen in this younger group. It may be more important to note that the use of diaphragm-based devices such as the Delta valve (Medtronic Corp.) and flow-control valves such as the OSV2 valve did not result in higher rates of complication as compared with simple differential pressure valves.2,5 Although the likelihood that late difficulties can be avoided by using these devices in combination with shunts cannot be proven at this time, their use is not harmful and it seems likely that their routine use will lead to improved late outcomes in older children and adults with shunt-dependent hydrocephalus.

Following up patients for a few years, especially when those patients are initially treated in infancy, is inadequate to assess the efficacy of a treatment strategy that is required throughout the life of a patient. An extremely long follow-up is required to determine if the strategy is or is not successful. These authors are to be congratulated for their involvement in shunt complication series remains identical to the results in our patients before we supplemented shunts with ASDs 25 years ago.14

The purpose of our study was not to determine the reason some patients are fortunate enough to grow up without shunt complications or become shunt independent, but to achieve efficient prevention of ventricular catheter occlusion.

Slit ventricle syndrome can take years before its clinical manifestation becomes apparent.16 Once the symptoms become exacerbated and require a proximal shunt revision, however, the risk of developing secondary complications, such as lost or fixated ventricular catheters, entrapped ventricles, or recurrent life-threatening exacerbation of ICP hypertension, increases drastically.2,3,5,14,17

In 1973 Fox et al.8,9 described a fundamental physical phenomenon in established shunts, which operate on a differential-pressure-valve principle. They documented that the function of every implanted shunt automatically switches from the intended passive pressure compensating drainage to an active suction drainage when the differential pressure in the shunt increases exponentially as soon as the patient assumes an upright position (hydrostasis). They concluded that the high rate of skull deformities, proximal shunt occlusions, subdural hygromas, entrapped

References


Disclosure

Dr. Rekate serves as a consultant for Codman.

Response

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Despite technological progress in new shunt designs and diagnostic advances in modern imaging facilities, shunt complication rates, particularly those caused by proximal shunt occlusion, remain alarmingly high.3,4,7,17 In fact, controversial interpretations of MR images with small ventricles despite intracranial hypertension and shunt patency (known as “symptomatic slit ventricle syndrome” [SVS] or “normal-volume hydrocephalus” have become additional challenges for shunt therapy.2,3,5,14,17

Various pathophysiological theories and therapeutic proposals have not been able to prevent these complications.3,18–20 Radiological misinterpretations of slit ventricles as “normal,” not acknowledging headache as a shunt problem, questioning the patients’ and parents’ liability, and referring the patient to migraine specialists or psychiatrists are not uncommon.3,5,6

Although the mentioned multicenter shunt design trial was only focused on the first shunt revision and the mean follow-up period was < 4 years, 60% of the shunts failed in the first 4 years—74% due to proximal ventricular catheter occlusion.4,15 This high rate of proximal catheter involvement in shunt complication series remains identical to the results in our patients before we supplemented shunts with ASDs 25 years ago.14

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ventricles, and the variety of SVS symptoms originated from this chronic hydrostatic suction.

With the ASD, they developed a simple device that when implanted at the skull base level inhibits the 0-level of the shunt’s differential pressure to sink to the level of the distal end of the shunt during the upright position.8,9

When we realized the menacing consequences of this unintended alteration in the shunt dynamics during mobilization, our approach to shunt patients, symptoms, diagnostic results, and therapeutic management fundamentally changed. Apparent paradoxical symptoms became obviously shunt related.10–14

In our experience the ASD proved highly effective in preventing these complications when it was initially added to a differential pressure valve and if placed at the crucial 0-level position close to the skull base and stabilized under scar-free galea. In addition, the ASD allowed continuous adaptation to growth at a pressure/suction proportion of 1:10.

Although we have no long-term experience with different antisiphoning, gravity-control, or flow-control devices, some may prove successful under specific circumstances. Pathophysiologival differences between children and adults and hypertensive and normal-pressure hydrocephalus require, however, a differentiated approach to shunt dynamics.17,19

The high pressure/suction proportion of the double-membrane suction-control device (1:20 in comparison to the 1:10 of the ASD) is more appropriate for adult shunt therapy and less effective for newborns and young children, which could explain the poor antisiphon effect in the aforementioned shunt trial.4,15

Antigravity valves inhibit suction when positioned vertically. However, the weight of the ball-in-cone must strictly correspond to the effective length of the hanging peritoneal catheter. Antigravity valves are established devices in lumbo-peritoneal shunting in adults, but lack the ability to adapt to growth during childhood.

Flow control devices (OSV, Siphon-Guard) reduce the velocity of CSF flow through the shunt but cannot restore the decreased 0-level or inhibit suction.

We firmly believe that the implantation of shunts without prophylactic suction protection is not responsible. Differential pressure valves, adjustable or nonadjustable, should be utilized solely in connection with an antisuction protection to prevent chronic CSF overdrainage before complications occur.

Our 25 years of experience with the prophylactic addition of an ASD to every shunt shows that the prevention of hydrostatic suction in a hanging shunt system can significantly reduce the frequency of proximal shunt complications and, more importantly, inhibit the development of symptomatic SVS and improve a patient’s quality of life.10–14 (DOI: 10.3171/2009.8.00249)

References