Shunting to the Sagittal Sinus

S. E. Borgesen, F. Gjerris, and N. Agerlin

University Clinic of Neurosurgery, Rigshospitalet, Copenhagen, Denmark

Summary

Objectives. To develop a shunt that drains CSF from the ventricles to the sagittal sinus under normal-physiological conditions. This shunting principle will not lead to any over-drainage, and a large proportion of the known shunt-complications will be avoided.

Methods. On the basis of the normal values for ICP, resistance to outflow and the production rate of CSF we have developed a shunt that drains CSF to the sagittal sinus and restores normal condition for the CSF dynamics. The shunt consists of two unidirectional valves, a pre-chamber, a resistance tube made of titanium, and a titanium tube leading CSF into the sagittal sinus. The shunt has been tested in 18 patients. Observation time ranged from 2 to 430 days, mean time 54 days.

Results. The first results from the use of the new shunt are very promising. It has an immediate effect on the clinical symptoms, it restores CSF dynamics (investigated with the shunt inserted) and the size of the ventricles is only gradually diminished. Slit ventricles have not yet been observed. In all patients the symptoms of hydrocephalus were relieved. No occlusion or thrombosis of the sagittal sinus have been observed. This is in agreement with the reports in the literature of shunting to the sagittal sinus, where 99 cases have been presented with an observation period of up to 6 years. The shunt has proven easy and safe to implant.

Conclusions. Shunting to the sagittal sinus has proven easy and safe with regard to short term results. By using a dedicated shunt that drains at normal physiological parameters for the CSF dynamics any over-drainage is avoided, and it may be expected that the complication rate will be substantially smaller than with existing shunting systems.

Keywords: Hydrocephalus; drainage into sagittal sinus.

Physiologic Principles

Shunting cerebrospinal fluid (CSF) means leading CSF from the site of accumulation to a resorption site outside the cerebrospinal cavity. The purpose of shunting CSF is to circumvent an obstruction which inhibits the outflow of CSF through its normal pathways during normal pressure/flow conditions.

The goal of CSF shunting is to restore the normal intracranial pressure balance. Shunting CSF to another cavity in the body, e.g. peritoneal cavity or the right atrium of the heart, inherits a disturbance of the normal CSF flow conditions. The draining systems used for diverting CSF from the cranio-spinal cavity to another resorption site are therefore constructed with the aim of re-establishing the normal intracranial pressure level. Shunting devices deploy a uni-directional flow mechanism and some sort of flow restriction working by a variety of principles but always depending on the differential pressure level across the shunting device. As the differential pressure is the resultant of the pressure in the CSF containing cavity and the pressure in the receiving compartment, the flow of CSF through the shunt depends on the pressure in both compartments [6].

Knowledge about the normal physiology of the CSF dynamics has made it possible to describe the pressure and flow conditions of the CSF from the production site to the receiving site. Comparison of the parameters of the normal CSF dynamics with the parameters obtained by shunting CSF to different receiving compartments explain some of the problems connected with shunting of hydrocephalus.

The intracranial pressure (ICP) depends on the CSF production, resorption resistance and pressure in the
receiving compartment. The relationship of these parameters are given by the Davson equation:

$$ICP = FR \times R_{out} + P_{ss},$$

where FR is the formation rate of CSF, $R_{out}$ is the resistance to CSF outflow and Pss is the pressure in the sagittal sinus [6].

From the normal values of FR, $R_{out}$ and ICP the relationship describing a steady state balance of CSF dynamics is shown in Fig. 1. The 2 curves demonstrate the flow of CSF when the ICP is increased i.e. by loading during infusion test where the pressure in the receiving compartment is unincreased (i.e. steady Pss level) (Curve A). The second curve illustrates flow in conditions where the pressure in the receiving compartment co-varies with the ICP (for example): the flow remains stable and the CSF volume in the CSF compartments remains unchanged (Curve B). With the normal formation rate of 0.3 ml/min. and the normal pressure difference between production and receiving compartments, the ICP will constantly be around 10 mmHg. Increasing ICP without increasing receiving compartment pressure will result in increased outflow of CSF.

From knowledge of the normal intracranial pressure [10, 11], the pressure of the sagittal sinus [3, 4], and the normal resistance to outflow of CSF [1, 8] a shunt designated for draining CSF into the sagittal sinus has been developed (SinuShunt [1]*). It has been designed to comply with these data for normalcy and thereby providing a near to normal physiological drainage of the CSF.

**Methods**

The shunt consists of a ventricular catheter made of silicone rubber, a valve mechanism preventing back-flow from the SS to the shunt or the ventricles, a pre-chamber made of silicone rubber for punctuation and testing the performance of the shunt, a resistance tube made of titanium and dimensioned to create a resistance to outflow equal to normal values (8 ml/min./mmHg), a housing for the valves and the resistance tube made of either polycarbonate or silicone rubber, and a silicone rubber drain leading to the titanium tube for insertion into the SS.

The shunt functions by diverting the CSF from the ventricles to the SS. It is based on the principle that there will always be a pressure difference between the ventricles of the brain and the SS, the pressure being higher in the ventricles than in the SS. If this pressure difference was negative the CSF would not be resorbed. It is possible that the pressure difference is reversed (i.e. the pressure in the SS being higher than the pressure in the ventricles) in short periods of time, but on average the pressure must be higher in the ventricles. Because of these possible reversed pressures, the shunt must be provided with an effective valve mechanism. By inserting two valve mechanisms on each side of the pre-chamber, it is possible to test the shunt by pumping the pre-chamber.

The shunt has been inserted in patients with obvious symptoms of hydrocephalus and expected immediate response to CSF-diversion. The objective of the clinical investigation was to establish the performance of the shunt, the safety of the surgical procedure, and the short time safety of the implantation of a drain in the sagittal sinus. The patients were followed for three months or more. Obligatory endpoints were improved consciousness, validated by Glasgow Coma Scale, disappearance of papillary edema, disappearance of headache and other pressure symptoms, and normalization of intracranial pressure and resistance to outflow of CSF in patients where the clinical improvement was unsatisfactory.

**Results**

The shunt has been implanted in 18 patients: 5 patients had hydrocephalus following subarachnoid haemorrhage, 4 had tumour in the III ventricle, 4 had cerebellar metastasis, and 5 had normal pressure hydrocephalus. The mean observation time was 132 days, range from 2 to 430 days.

One patient developed infection immediately after implantation, and the patient was withdrawn from the

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* SinuShunt®, CSF-Dynamics, Naverland 2, 2600 Glostrup, Denmark