Clinical Experience with the Denver Shunt: A New Silicone-Rubber Shunting Device for the Treatment of Hydrocephalus

Technical Note

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Dissatisfaction with currently marketed devices for the treatment of hydrocephalus has provided the impetus for the development of a new shunting system. Problems attendant to shunt placement are many, consisting primarily of: 1) erratic performance or blocking of the device in vivo, especially in the presence of particulate contamination or unusually elevated protein levels of the cerebrospinal fluid; 2) a significant incidence of infectious complications, conceivably related to non-autoclavable devices with metallic components or plastic devices with complex recessing; and 3) the appreciable expense of the shunting device itself. The latter factor limits the availability of the operative procedure to a restricted population of patients within a favored social setting.

Our objective has been to develop an inexpensive device of simple yet rugged construction, devoid of metallic parts, capable of passing fluid of high viscosity or particulate contamination without obstruction. This report deals with a description of a new shunting system, "the Denver shunt" designed to meet these specifications, and our initial surgical experiences with this device in 57 patients at the University of Colorado Medical Center over an 18-month period.

Description and Flow Characteristics

The bodies of the Denver shunt are molded and vulcanized in one piece from Silastic. The proximal valve of the shunt is a simple slit contained within the molded part and analogous to a venous valve. The distal valve consists of two slits at the exit end of the distal tube (Fig. 1). The simplicity of design runs counter to the current developmental trend of more complicated and expensive shunting systems. Both the proximal and distal slits in the shunt act as one-way valves. A positive-pressure gradient in the direction of flow causes the valves to open, permitting CSF passage at a rate approximately proportional to the pressure gradient (Fig. 2). A negative pressure gradient forces the valve lips closed and prevents back flow. The net effect is a rectification of the venricular pressure pulses, allowing flow of cerebrospinal fluid in proportion to their intensity.

Bench tests of the Denver shunt performed with solutions of widely varying protein concentrations, including the addition of whole blood to artificial spinal fluid, show favorable flow properties in spite of high protein concentration (Fig. 2). Apparently the increasing viscosity of the protein solution is balanced by increased adsorption of protein on the slit lips. As a result the slit corners are pushed further apart, dilating the slit to accommodate the viscosity increase.

The axis of the proximal slit valve is maintained at an attitude perpendicular to the cranial vault by means of tabs projecting from the equator of the shunt body (Fig. 3). This critical feature permits selected or simultaneous flushing of all three shunt apertures (ventricular, proximal slit, and distal slit valves) by direct depression of the valve body at the proximal slit. Pumping the cylindrical housing distal to the proximal slit provides forward flow of cerebrospinal fluid only when the distal slits are incorporated in the system. With this shunt design, the flow rate can be reduced to zero by squeezing the proximal slit in the plane of the ears and releasing. If the proximal slit is squeezed normal to the plane of the ears and released, the

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* The Denver shunt is available from Denver Biomaterials, Inc., 2551 E. Floyd Avenue, Denver, Colorado 80210.
* Medical grade silicone-rubber manufactured by Dow-Corning.
slit is opened and the shunt will now give the calibrated flow rate at a 10 cm pressure head. In the latter condition the shunt has a flow rate approximately proportional to the pressure head, and therefore the flow rate will reach zero only when the pressure head is

![Diagram of Denver hydrocephalus shunt. Note attitude of proximal slit valve perpendicular to cranial vault.](image)

**Fig. 1.** Diagram of Denver hydrocephalus shunt. Note attitude of proximal slit valve perpendicular to cranial vault.

![Flow characteristics of typical “high flow rate” Denver shunt.](image)

**Fig. 2.** Flow characteristics of typical “high flow rate” Denver shunt. Hemoglobin addition was a 1:200 dilution of fresh blood in artificial spinal fluid containing protein at a level of 1 gm%. Distances marked by dot signify two standard deviations of the mean at each dot (five separate determinations at each dot).