Normal rate of cerebrospinal fluid formation five years after bilateral choroid plexectomy

Case report

THOMAS H. MILHORAT, M.D., MARY K. HAMMOCK, M.D.,
TECHEN CHIEN, M.D., AND DONALD A. DAVIS, PH.D.

Departments of Neurosurgery, Children's Hospital National Medical Center, and
George Washington University School of Medicine, Washington, D.C., and the
Branch of Surgical Neurology, National Institute of Neurological and Commu-
icative Disorders and Stroke, Bethesda, Maryland

A ventricular perfusion technique was used to determine the rate of cerebrospinal fluid (CSF) formation in a 5-year-old child who had undergone bilateral choroid plexectomy for communicating hydrocephalus during infancy. At the time of the study, the patient had a failed ventriculoperitoneal shunt and was suffering from progressive ventriculomegaly. The calculated rate of CSF formation, 0.35 ml/min, ± 0.02 standard deviation, was within normal limits.

KEY WORDS □9 cerebrospinal fluid □9 choroid plexus □9
choroid plexectomy □9 cerebrospinal fluid formation rate

The failure of choroid plexectomy as a treatment for hydrocephalus is amply documented in the literature, and has been ascribed to the continued formation of cerebrospinal fluid (CSF) at extrachoroidal sites. Although it has been shown that experimental extirpation of the choroid plexuses reduces the rate of CSF formation by 40% or less, there are no previous reports dealing with the rate of CSF formation in humans following choroid plexectomy. The patient reported here was the last to undergo bilateral extirpation of the lateral ventricle choroid plexuses for hydrocephalus in our clinic. An opportunity was afforded to measure the rate of CSF formation when the patient presented 5 years later with a failed ventriculoperitoneal shunt and evidence of progressive ventriculomegaly on serial cranial computed tomography (CCT) scans.

Case Report

A 3-week-old baby boy with meningitis and ventriculitis developed severe communicating hydrocephalus (Fig. 1). In spite of systemic antibiotics, the ventriculitis persisted and the head circumference increased at a rate of 2 cm per week. In July, 1970, at the
FIG. 1. Ventriculogram performed in June, 1970, demonstrating severe communicating hydrocephalus.

age of 5 weeks, the patient underwent staged operations\textsuperscript{12,15} for removal of the lateral ventricle choroid plexuses (Fig. 2). For 3 months the patient did well. Thereafter, the head circumference again began to increase at an excessive rate and at 5 months of age he required a ventriculoperitoneal shunt for progressive hydrocephalus. Over the next few years, the patient remained asymptomatic. He was able to attend regular nursery school classes and was found to be without abnormal neurological findings. A CCT scan in September, 1974, demonstrated generalized ventriculomegaly (Fig. 3 left). Following revision of a failed shunt in January, 1975, the patient complained of episodic nausea and vomiting and was noted to walk with a somewhat broadly-based gait. The reservoir of the shunt was easy to compress but did not refill. A CCT scan on April 25, 1975, demonstrated a significant increase in ventricular size (Fig. 3 right). Prior to revision of the shunt, a ventricular perfusion study was performed to measure the rate of CSF formation. The technique and results of the study are described below. The patient underwent a successful shunt revision the following day. He is currently doing well.

**Ventricular Perfusion Study**

This study was obtained with the informed consent of both parents and the approval of the Research Committee of Children's Hospital National Medical Center. The patient was sedated with 0.5 mg/lb of meperidine hydrochloride (Demerol) and 0.5 mg/lb of promethazine hydrochloride (Phenergan). Vital signs, including blood pressure, pulse, respiration, pupillary responses, and level of consciousness were monitored and recorded every 15 minutes. An intravenous (IV) infusion of 5\% dextrose and 1/3 normal saline was administered at a rate of 30 cc/hr. Continuous sedation was maintained throughout the procedure by administering small supplemental doses of Demerol and Phenergan intravenously.

To be certain that there would be no loss of perfusate through the obstructed shunt, the peritoneal catheter was ligated through a small scalp incision just below its connection with a Pudenz reservoir. A No. 20 spinal needle, 2½ in. in length, was then passed into the frontal horn of the right lateral ventricle after penetrating the skull with a bone marrow needle. A No. 20 spinal needle, 1½ in. in length, was introduced into the lumbar theca. The CSF pressure, measured manometrically in the lateral decubitus position, was 150-mm water in the lumbar theca. Table 1 shows a chemical
analysis of simultaneously obtained specimens of blood and lumbar CSF.

With the patient lying in the lateral decubitus position, artificial CSF (Elliott's B solution) containing 10 μCi of 131I human serum albumin per liter was infused with a Harvard pump* through the ventricular (inflow) needle and collected from the lumbar (outflow) needle. The ventricular perfusion pressure, 150-mm water, was determined by setting the height of the orifice of the outflow tubing. After washing out the system with perfusate for 2 hours, a perfusion rate of 2.27 ml/min was established. Aliquots of fluid were sampled every 10 minutes for 4 hours from the outflow needle; control samples from the inflow needle were obtained at the beginning and end of the study. The concentration of 131I albumin in the samples was

*Harvard pump manufactured by Harvard Apparatus, 150 Dover Road, Millis, Massachusetts 02054.

### TABLE 1

<table>
<thead>
<tr>
<th>Chemical Analysis</th>
<th>Cerebrospinal Fluid</th>
<th>Blood Plasma</th>
</tr>
</thead>
<tbody>
<tr>
<td>glucose (mg/dl)</td>
<td>60</td>
<td>198</td>
</tr>
<tr>
<td>blood urea nitrogen (mg/dl)</td>
<td>7</td>
<td>11</td>
</tr>
<tr>
<td>CO₂ (mEq/l)</td>
<td>28</td>
<td>26</td>
</tr>
<tr>
<td>sodium (mEq/l)</td>
<td>145</td>
<td>138</td>
</tr>
<tr>
<td>potassium (mEq/l)</td>
<td>2.7</td>
<td>3.5</td>
</tr>
<tr>
<td>chloride (mEq/l)</td>
<td>119</td>
<td>101</td>
</tr>
<tr>
<td>calcium (mg/dl)</td>
<td>4.7</td>
<td>9.4</td>
</tr>
<tr>
<td>phosphorus (mg/dl)</td>
<td>1.7</td>
<td>4.8</td>
</tr>
<tr>
<td>magnesium (mg/dl)</td>
<td>2.5</td>
<td>1.6</td>
</tr>
<tr>
<td>creatinine (mg/dl)</td>
<td>0.6</td>
<td>0.6</td>
</tr>
<tr>
<td>uric acid (mg/dl)</td>
<td>3.7</td>
<td>3.9</td>
</tr>
<tr>
<td>lactic dehydrogenase (mU/ml)</td>
<td>30</td>
<td>124</td>
</tr>
<tr>
<td>total protein (mg/dl)</td>
<td>74</td>
<td>6.4 gr/dl</td>
</tr>
<tr>
<td>albumin</td>
<td></td>
<td>3.8</td>
</tr>
<tr>
<td>globulin</td>
<td></td>
<td>2.6</td>
</tr>
<tr>
<td>osmolality</td>
<td>296</td>
<td></td>
</tr>
<tr>
<td>color</td>
<td>clear</td>
<td></td>
</tr>
<tr>
<td>red blood cell count</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>white blood cell count</td>
<td>2 (lymphs)</td>
<td></td>
</tr>
</tbody>
</table>

Fig. 3. Cranial computed tomography scans. Left: September, 1974, scan demonstrates generalized ventricular enlargement. A shunt catheter is present in the occipital horn of the right lateral ventricle. Right: April, 1975, scan demonstrates a significant increase in ventricular size as compared with the earlier study. The occipital horn of the right lateral ventricle is only partially visualized, suggesting intraventricular adhesions and obstruction of the shunt catheter.
FIG. 4. Counts of 131I albumin in influent (C_i) and effluent (C_o) as a function of time. Perfusion rate is 2.27 ml/min.

determined in a well-type scintillation counter operating at 35% efficiency. Dialyzed samples of CSF did not demonstrate any significant unbinding of the isotope.

Figure 4 plots the counts of 131I albumin in the influent (C_i) and effluent (C_o) as function of time. As can be seen, a very stable steady-state perfusion was achieved after the initial 2-hour washout. The dilution factor of the effluent was approximately 15%. Using equations derived from Heisey, et al., we calculated the CSF formation rate to be 0.35 ml/min, with a standard deviation (SD) of ± 0.02.

Discussion

The failure of choroid plexectomy to cure or significantly benefit most patients with hydrocephalus has been difficult to reconcile with Dandy's view that the choroid plexuses are the sole source of the CSF. This has led to a critical reexamination of the basic mechanisms underlying CSF formation. In recent years, evidence has been accumulating that a significant fraction of CSF is formed at extrachoroidal sites within the cerebral ventricles. Following extirpation of the choroid plexuses in rhesus monkeys, for example, the rate of CSF formation in the chambers rostral to the fourth ventricle is reduced by only 40% or less. It has been stressed that such data do not necessarily mean that more than 60% of the CSF is formed at extrachoroidal sites under normal conditions; however, the production of large volumes of CSF following choroid plexectomy is clinically important and has been cited as the probable cause for the failure of this procedure as a treatment for hydrocephalus.

Clinical studies dealing with the physiological consequences of choroid plexectomy have been limited. In previous reports from our own clinic, it has been shown that the transventricular absorption of radiiodinated albumin is reduced in some patients following bilateral choroid plexectomy and in eight of 12 patients the postoperative rate of ventricular enlargement was found to be at least as rapid as that recorded preoperatively. However, in no previous report has the rate of CSF formation been accurately determined following surgery.

In the case reported herein, the rate of CSF formation was determined in a 5-year-old child who had undergone bilateral extirpation of the lateral ventricle choroid plexuses during infancy. At the time of the study, the patient had a failed ventriculoperitoneal shunt and was suffering from progressive ventriculomegaly. The technique for measuring CSF formation, ventriculolumbar perfusion, has been successfully employed in human subjects with hydrocephalus and unobstructed CSF pathways and is more precise than continuous ventricular drainage since it minimizes errors attendant to changes in intraventricular pressure and volume.

With the exception of total protein concentration, the chemical composition of lumbar CSF in the current case was normal (see Table 1). This finding is consistent with previously published data and indicates that the CSF formed by the plexectomy ventricular system is not a pathological exudate. The slightly elevated total protein in our case may have been due to the effects of past intraventricular infection, subsequent surgical procedures, or both.

As shown in Fig. 4, a very stable steady-state perfusion was achieved within 2 hours. The calculated rate of CSF formation, based on equations derived from Heisey, et al., was 0.35 ml/min, ± 0.02 SD. This value compares favorably with the mean rate of 0.35 to 0.37 ml/min in patients with unobstructed CSF pathways and is slightly higher than the mean rate of 0.30 ml/min, ± 0.02 SD, reported in patients with hydrocephalus.

Since the preoperative rate of CSF formation in this patient is not known, no conclusions can be reached concerning the quantitative effects of bilateral choroid plexectomy.
However, the finding of a normal rate of CSF formation 5 years postoperatively is of obvious clinical interest and explains the progressive ventriculomegaly that occurred following obstruction of a functioning ventricular shunt. From a management standpoint, it is anticipated that our patient will be indefinitely dependent upon a ventricular shunt.

References

Address reprint requests to: Thomas H. Milhorat, M.D., Department of Neurosurgery, Children's Hospital, National Medical Center, Washington, D.C. 20009.