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Determination of ventricular fluid outflow resistance in patients with ventriculomegaly

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Abstract

Resorption of the ventricular fluid was studied by measuring ventricular fluid outflow resistance during steady state 1·5 and 5·0 ml/min infusions in 26 patients with substantial enlargement of the supratentorial ventricular system. This test may avoid unnecessary use of shunts, but a shunt could be introduced during the same procedure.

It can be difficult to decide how to treat a patient whose CT scan shows hydrocephalus and who does not show increased intracranial pressure, but does have lesser symptoms such as headache, dizziness, impaired memory, unsteady gait, and urine incontinence. The diagnostic tests commonly used in such patients include cisternography and the measurement of the cerebrospinal fluid (CSF) outflow resistance. These tests are usually performed by the lumbar route.[1 2] A prerequisite for this approach is free communication between lumbar CSF and the ventricular fluid. If there is aqueduct occlusion or leptomeningeal adhesions, the test will be misleading and potentially dangerous. This study was not only undertaken to avoid shunt procedures in patients with proven ventriculomegaly and normal outflow resistance but also to explore the feasibility of both intraventricular testing[3] and direct shunting as a one stage procedure.

Material and method

We studied twenty six hydrocephalic patients having CSF dynamic studies and ventriculoperitoneal shunt procedures. The patients had possible or probable occlusion of the aqueduct where lumbar liquordynamic studies would be misleading, or patients in whom lumbar CSF infusion tests had given inconclusive results.

There were 12 females and 14 males aged one to 74 years, mean 37 years (table). Clinical symptoms and signs included intellectual impairment, headache, ataxia and urine incontinence of varying degrees. CT scans demonstrated marked supratentorial ventricular enlargement including the third ventricle, but no enlargement of the fourth ventricle. There were no distinct periventricular lucencies, nor were the basal cisterns compressed and the subarachnoid spaces over the hemispheres were at least partially preserved. There were thus no cases of "pressure hydrocephalus" as judged by clinical evaluation and CT scans, and the indication for shunting was considered to be uncertain.

In the first 10 patients the ventricular cannula was implanted in the right frontal horn

Table Test data for the 26 patients

Pat. num.	*Age Sex*	*Po*	*Pp 1·5 ml/min*	*Pp 5·0 ml/min*	*Ro 1·5*	*Ro 5·0*	*Shunt*	*Clinical improvement*
1	16, F	20	40	74	13·3	10·8	+	++
2	68, F	4	16	42	8·0	7·6		
3	60, M	8	24	54	10·6	9·2		
4	45, F	10	20	44	6·7	6·8		
5	73, M	4	30	72	17·3	11·6	+	+
6	60, M	10	20	42	6·7	6·4		
7	17, F	0	10	24	6·7	4·8		
8	20, M	2	10	24	5·3	4·4		
9	66, M	10	40	70	20·0	12·0	+	++
10	10, M	2	10	25	5·3	4·6		
11	2, F	10	22	45	8·0	7·0		
12	32, F	10	30	56	13·3	9·2	+	+
13	60, F	10	30	56	13·3	9·2	+	++
14	71, F	8	36	52	18·7	8·8	+	−*
15	20, F	10	30	54	13·3	8·8	+	+
16	49, F	12	24	44	8·0	6·4	+	−**
17	21, M	14	32	64	12·0	10·0	+	++
18	63, F	15	34	76	12·7	12·2	+	+
19	63, F	16	28	48	8·0	6·4	+	(+)
20	13, M	6	18	44	8·0	7·6	+	−
21	36, M	6	16	30	6·7	4·8		
22	44, M	6	16	30	6·7	4·8		
23	74, M	2	20	50	12·0	9·6		
24	45, M	9	40	80	20·7	14·2	+	+
25	1, M	9	16	31	4·7	4·4		
26	11, M	5	15	38	6·7	6·6		

F, female; M, male; Po, opening pressure; Pp, plateau pressure; Ro, outflow resistance; Clinical improvement: − no improvement; (+) − doubtful improvement; + moderate improvement; + + marked improvement.
*the patient deteriorated due to myocardial failure and died 2 weeks after surgery.
**Downs syndrome.

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during local anaesthesia. The intraventricular pressure (IVP) was recorded at midcranial level by standard fluid pressure transducers (AME, Horten, Norway). The tubing and the dome of the transducer were prefilled with artificial CSF from the infusion pump (Braun-Melsungen, FRG) to avoid leakage of ventricular fluid. The IVP was continuously recorded on conventional strip charts at 1 cm/min. All IVP values were the integrated mean values given by the pressure module (Hewlett Packard, FRG).

After a steady state baseline IVP was established (opening pressure) a constant rate 1·5 ml/min infusion test was performed.[3] After the pressure returned to baseline level, a constant rate 5·0 ml/min infusion test was performed. The ventricular catheter was removed after the test and shunting procedure was performed two days later.

In the last 16 patients (table) the tests were performed during general anaesthesia to reduce the number of ventricular punctures, to ensure constant $PaCO_2$ during the test and to enable implantation of a full shunt system at the same procedure. General anaesthesia was induced with barbiturates, fentanyl and alcuronium, and maintained with nitrous oxide (N_2O/O_2:70/30). The tests were performed during normocapnia ($PaCO_2$ 4·8–5·1 kPa) and end-tidal pCO_2 was continuously monitored by standard capnographs (Datex, Finland).

The plateau values were determined for all patients both from the 1·5 ml/min and the 5·0 ml/min infusion test; outflow resistance was calculated from the formula:[4] Ro = (Pp–Po)/infusion rate, where Pp is the plateau pressure and Po the opening pressure. Patients who demonstrated plateau pressure levels of at least 30 mm Hg and an outflow resistance of at least 12 mm Hg/ml/min at the 1·5 ml/min infusion test were given Holter medium valve ventriculoperitoneal shunt.

In the 16 patients tested during general anaesthesia radial artery blood pressure (ABP) was monitored with IVP to ensure a cerebral perfusion pressure (CPP = ABP − IVP) of at least 30 mm Hg throughout the test. They were also observed for changes in ABP and heart rate during the test.

Results

The opening pressures and plateau values for constant infusion rate tests with 1·5 ml/min as well as 5·0 ml/min are listed in the table. In the first 10 patients in whom the tests were performed with local anaesthesia, the plateau pressures at 5 ml/min in the range of 24 to 74 mm Hg were remarkably well tolerated, almost without any clinical symptoms. Outflow resistance (Ro) derived from plateau pressures (Pp) and opening pressures (Po) at both infusion tests are given in the table. Outflow resistance derived from the 1·5 ml/min infusion test ranged from 4·7 to 20·7 mm Hg/ml/min, while the Ro values derived from the 5·0 ml/min tests ranged from 4·4 to 14·2 mm Hg/ml/min.

The time taken to reach plateau value at 1·5 ml/min test ranged from 15 to more than 40 minutes in these patients with marked supratentorial ventriculomegaly. With 5 ml infusion, however, the plateau pressure was reached within five to 10 minutes in all patients.

Ten patients were given shunts because they had ICP plateau values of at least 30 mm Hg (over 40 cm H_2O) and Ro of 12 mm Hg/ml/min. Four of the patients demonstrated marked and another four moderate clinical improvement after shunting (table). Another three patients had values below these, but were shunted because they had relatively marked clinical symptoms and signs (patients 16, 19, 20). Nine of the patients improved clinically. All the patients who were shunted showed some reduction in ventricular size on subsequent CT scans and have been followed for at least three years. Two shunts have been revised because of shunt failure, with renewed improvement.

There were no adverse effects to the tests and none of the shunts became infected. All the patients who had been given shunts were given cefalothin, 14 mg/kg four times during the first 24 hours.

Discussion

Our results agree with previous reports that increased CSF outflow resistance above 12 mm Hg/ml/min predicts which patients are likely to benefit from the insertion of a shunt.[5–7] In the type of patients we studied, with enlarged supratentorial ventricles but a normal fourth ventricle, the presence of aqueduct obstruction must be considered. This was confirmed in five of eight patients who had metrizamide ventriculography.

In patients with possible or probable aqueduct obstruction many neurosurgeons recommend shunting without preoperative hydrodynamic testing, basing their decision on clinical and radiological grounds. Some believe that shunting is justified even if there is only a slight chance of improving the patient, particularly in the elderly. It is less easy in young and middle aged individuals and at all ages it is necessary to consider the risk of complications such as an extracerebral haematoma.

Determining the ventricular fluid outflow resistance was uneventful in these 26 patients. In ten of the last 16 patients, a full shunt procedure was performed at the same operation. However, using the 1·5 ml/min infusion rate, it could take 15 to 45 minutes to reach the plateau pressure. In patients where the test is performed during general anaesthesia a total test time of 30 to 60 minutes is too long. The 5·0 ml/min test gave an outflow resistance (Ro) in five to 10 minutes and in patients with low or normal Ro, accurately predicted the resistance. However, in patients with moderately or considerably increased Ro, the high rate infusion test underestimated the outflow resistance as determined by the 1·5 ml/min infusion. This implies that if the ven-

tricular pressure increases only very slightly after 10 minutes of 1·5 ml/min infusion, the infusion rate can safely be increased to 5 ml/min. If the ventricular pressure should rise unexpectedly, the test can be stopped immediately and ventricular fluid drained if necessary. Concomitant monitoring of the arterial blood pressure is recommended to ensure a reasonable perfusion pressure, especially at high levels of ventricular fluid pressures. Patients with only moderately enlarged ventricles, especially in cases of aqueduct occlusion, may not tolerate increases in the ventricular pressure to more than 15–20 mm Hg. If there is bradycardia or an increase in blood pressure the infusion is stopped immediately and CSF drained.

Permanent shunting was avoided in half of the patients in this series. The lack of clinical improvement in the three patients who were given shunts in spite of Ro values below 12 mm Hg/ml/min indicates that it may not be helpful to shunt when the outflow resistance is below this value.

The one stage "test and shunt if needed" policy used in the latter part of this study was found feasible and practical. The number of procedures as well as the length of the hospital stay was thereby reduced.

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