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Functioning Periods and Complications of 246 Cerebrospinal Fluid Shunting Procedures in 208 Children

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To investigate the functioning periods and the causes of cerebrospinal fluid shunt failures, 246 shunts inserted in 208 children from October 1985 to August 1992 at the authors' institute were retrospectively reviewed. The mean age at shunt insertion was 4.0 years and the reasons for the shunting procedures were congenital hydrocephalus (47.6% per procedure), tumor-associated hydrocephalus (21.1%), postmeningitic hydrocephalus (11.8%), congenital cyst (10.6%) and others (8.9%). All except 2 were shunted to the peritoneal cavity.

Forty-five operations for shunt failure were done (18.3%) during the follow-up period (mean, 32 months). The functioning (shunt survival) rates at 6, 12, 24 and 36 months after surgery were 91.6%, 86.6%, 83.6% and 82.9%, respectively. The complications were mechanical malfunction (12.2%), infection (4.1%), subdural fluid collection which required drainage (1.6%) and migration (0.4%). About half of the mechanical malfunctions and infections which had occurred during the follow-up period were within 6 months and 2 months after surgery, respectively. There was no shunt-related mortality. These chronological data should be considered in the planning of follow-up schedules.

Key Words: *Cerebrospinal fluid shunt, Complication, Shunt survival*

INTRODUCTION

Since the introduction of cerebrospinal fluid (CSF) shunting procedures, it has been one of the main methods in the management of hydrocephalus or intracranial fluid collection. However, the installation of foreign material in the human body has some limitations in itself. Predisposition to mechanical disintegrity, infection and non-physiological flow of CSF led to considerable complications and shunt failures. Ten to 57% complication rates have been recorded (Fibla et al., 1983; Zingg et al., 1987; Choudhury, 1990). In Korea it has been reported as 27.4% to 36.7% (Hu et al., 1987; Cho et al., 1988; Shin et al., 1989). There are many articles describing the incidence and treatment outcome of CSF shunt complications. However, only a few studies have shown the chronological pattern of shunt failure or shunt survival (functioning period) applying the methods used in the survival analysis of tumor patients (Bierbrauer et al., 1990-1991; Piatt and Carlson, 1993; Piatt, 1994).

To investigate the pattern of CSF shunt failures in a

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Table 1. Reasons and ages in 246 shunting procedures.

Age(years) / Etiology	<1	1~5	6~10	11~15	Total(%)
congenital	61	32	17	7	117(47.6)
tumor	5	16	15	16	52(21.1)
meningitis	13	12	2	2	29(11.8)
arachnoid cyst	6	10	6	2	24(9.8)
hemorrhage	3	1	0	4	8(3.2)
trauma	1	1	2	1	5(2.0)
surgery	1	2	0	0	3(1.2)
porencephalic cyst	0	1	0	0	1(0.4)
neuroepithelial cyst	0	0	1	0	1(0.4)
unknown	2	1	1	2	6(2.4)
Total	92	76	44	34	246(100)

pediatric population, 246 shunts inserted in 208 children from October 1985 to August 1992 at Seoul National University Children's Hospital were retrospectively reviewed and the shunt survival curves were figured out. The causes of failure were also analyzed.

MATERIALS AND METHODS

Patient population

Two hundred and forty-six CSF shunting procedures performed in 208 children (up to 15 years old) from October 1985 to August 1992 at the Division of Pediatric Neurosurgery of Seoul National University Children's Hospital were reviewed. Patients who underwent the first shunting procedure at other institutes and procedures inserting a part of a shunt system (Ommaya reservoir, etc.) were excluded. Cases of congenital cysts or persistent subdural fluid collection were included. The mean age at the insertion of shunt was 4.0 years and 145 procedures were done for boys and 101 for girls.

Reasons for CSF shunting procedures

The reasons for shunting procedures were congenital hydrocephalus in 117 procedures (47.6% per procedure), tumor-associated hydrocephalus in 52 (21.1%), postmeningitic hydrocephalus in 29 (11.8%), congenital cyst in 26 (10.6%) and others in 22 (8.9%). The reasons and ages in 246 shunting procedures are summarized in Table 1.

Types of shunting procedures

All except 2 were shunted to the peritoneal cavity. Ventriculoatrial and ventriculopleural shunts were installed in one case, each. In 26 cases, the proximal catheter was not placed into the ventricular space (25 in cyst, 1 in subdural space, Table 2). All the shunts inserted were composed of three pieces. The majority of them (228/246, 92.7%) were Accu-Flo system (Codman) and others were Pudenz, Foltz or mini-LPV system (Heyer-Schulte). Type of reservoir/valve (burr hole type vs. flat bottom), site of ventriculostomy (frontal vs. posterior parietal), opening pressure of shunt system varied on each patient. The influence of these variables on mechanical malfunction will be analyzed in another study.

Shunt survival

The interval from the insertion of a shunt system to revision, removal or externalization was regarded as the functioning period of shunt (shunt survival). An addition of ventricular catheter to another isolated compartment was not regarded as a shunt failure but censored. Though the shunt continued to work even if the subdural fluid collection was drained, the drainage

Table 2. Types of 246 shunting procedures.

Type	No. of Cases (%)
ventriculo-peritoneal	215(87.4)
ventriculo-cysto-peritoneal	1(0.4)
ventriculo-subduro-peritoneal	2(0.8)
cysto-peritoneal	25(10.2)
subduro-peritoneal	1(0.4)
ventriculo-atrial	1(0.4)
ventriculo-pleural	1(0.4)
Total	246(100)

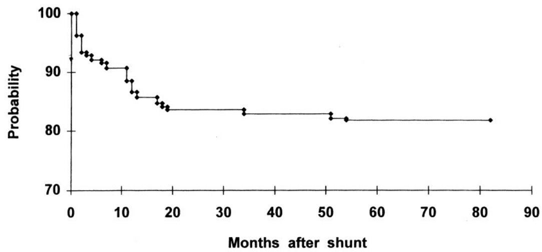

Fig. 1. Overall shunt survival curve which shows the complication-free probability. The overall shunt survival rates at 1, 2, 3, 6, 12, 24 and 36 months after surgery were 96.3%, 93.4%, 92.5%, 91.6%, 86.6%, 83.6% and 82.9%, respectively.

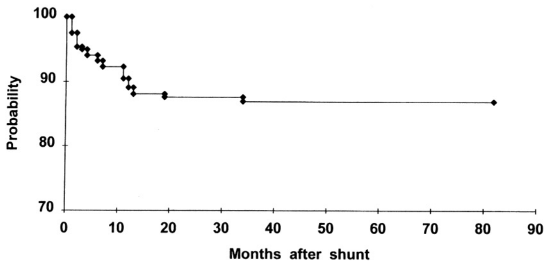

Fig. 2. Mechanical malfunction-free shunt survival curve. The mechanical malfunction-free survival rates at 1, 2, 3, 6, 12, 24 and 36 months after surgery were 97.6%, 95.4%, 95.0%, 93.2%, 89.1%, 87.6% and 86.9%, respectively. About half of the mechanical malfunctions which occurred during the follow-up period (6.8% out of 13.1%) were within 6 months after surgery.

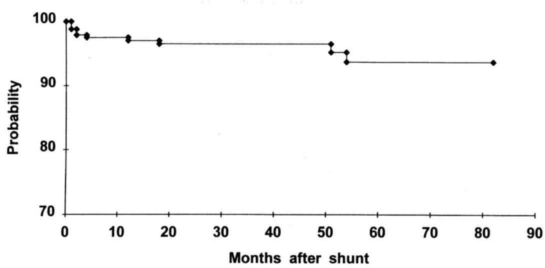

Fig. 3. Infection-free shunt survival curve. The infection-free survival rates at 1, 2, 3, 6, 12, 24 and 36 months after surgery were 98.8%, 97.9%, 97.9%, 97.5%, 97.0%, 96.5% and 96.5%, respectively. About half of the infections (2.1% out of 3.5%) which occurred during the follow-up period were within 2 months after surgery.

of subdural fluid which had accumulated after shunt insertion was counted as a shunt failure. Three shunt survival curves were figured out for overall complications, mechanical malfunction and infection. Survival curves were made according to Kaplan-Meier method. Also the complications which led to shunt failures were listed. The mean duration of follow-up at the end of August 1992 was 32 months.

RESULTS

The overall shunt survival rates at 1, 2, 3, 6, 12, 24 and 36 months after surgery were 96.3%, 93.4%, 92.5%, 91.6%, 86.6%, 83.6% and 82.9%, respectively (Fig. 1). The mechanical malfunction-free survival rates at 1, 2, 3, 6, 12, 24 and 36 months after surgery were 97.6%, 95.4%, 95.0%, 93.2%, 89.1%, 87.6% and 86.9%, respectively. About half of the mechanical malfunctions which occurred during the follow-up period (6.8% out of 13.1%) were within 6 months after surgery (Fig. 2). The infection-free survival rates at 1, 2, 3, 6, 12, 24 and 36 months after surgery were 98.8%, 97.9%, 97.9%, 97.5%, 97.0%, 96.5% and 96.5%, respectively. About half of the infections (2.1% out of 3.5%) which occurred during the follow-up period were within 2 months after surgery (Fig. 3). There were 2 infections at more than 2 years after shunting procedures. The 2 infections which actually occurred at more than 4 years after surgery were one postoperative infection after removal of a pituitary tumor and one from insect-bite related cellulitis of the skin overlying the distal tubing.

Forty-five operations for shunt failure were done (18.3%) during the follow-up period. The reasons for failure were mechanical malfunction (12.2%), infection (4.1%), subdural fluid collection (1.6%) and migration (0.4%) (Table 3).

The whole system was revised in 34 and parts of the system were changed in 7 failures. There was no mortality related to shunt complications.

Table 3. Complications which led to shunt failure in 246 procedures.

Complication	No. of Failures		(%)
mechanical malfunction	30		(12.2)
obstruction		24	(9.8)
breakage or kinking		3	(1.2)
proximal malposition		2	(0.8)
disconnection		1	(0.4)
infection	10		(4.1)
subdural fluid collection	4		(1.6)
migration	1		(0.4)
Total	45		(18.3)

DISCUSSION

Though the shunting procedure is one of the main treatment modalities of disturbed CSF dynamics, it has several disadvantages over other general neurosurgical operations. In spite of continued efforts to improve the hardware and the surgical technique, mechanical malfunction, infection and non-physiological drainage of CSF are the leading causes of shunt failure (Cho et al., 1988 ; Aldrich and Harmann, 1990-1991 ; Piatt and Carlson, 1993 ; Sainte-Rose, 1993). Though the overall complication rates differ depending on patient population (age, reason of shunting procedures, etc.), institutes, duration of follow-up, shunt device and route used, and perioperative management protocol, the majority of series have reported complication rates of 10% to 57% (Fibla et al., 1983 ; Zingg et al., 1987 ; Choudhury, 1990). In Korea it has been reported as 27.4% to 36.7% (Hu et al., 1987 ; Cho et al., 1988 ; Shin et al., 1989). In the present series, it was 18.3% at the mean follow-up duration of 32 months. With appropriate selection of shunt device, better placement of ventricular catheter tip, strict aseptic procedures and skin care, and avoidance of unnecessary shunting procedures, the complication rate is expected to decline.

Mechanical malfunction is the most frequent cause of shunt failure in most investigations. Fibla et al. (1983) reported a high obstruction rate of 25% while Choudhury (1990) had a much lower rate, 2.5%. Bierbrauer et al. (1990-1991) insisted on the better outcome of the posterior route of ventricular catheter placement over that of the frontal route reporting 1-month and 2-year functioning rates for the posterior route as 88.3% and 66.3%, respectively. Sainte-Rose et al. (1991-1992) showed a 81% malfunction rate at 12 years after surgery. Piatt and Carlson (1993) reported the median survival of simple shunt as 73 months and 2-year survival rate as 80%. Sainte-Rose (1993) described 1-year and 5-year failure rates as 31.1% and 49%, respectively. In Korean articles the mechanical malfunction rates have been recorded as 15.3% to 41.1% (Hu et al., 1987 ; Cho et al., 1988 ; Shin et al., 1989). Though the patient population and other various influencing factors differ from those of previous reports, the mechanical malfunction-free survival rates of the present study, whose rate was 87.6% at 2 years after surgery, are better. Sainte-Rose (1993) stated that the risk of shunt obstruction follows a two-phase curve : the first phase is related to a passive phenomenon induced by debris, clot or bacterial proliferation, while the second is related to a more active phenomenon generated by rapid changes in CSF flow through the tubing which causes the migration of tissues such as choroid plexus and ependyma. In the present study such a two-phase curve could not be observed.

Infection is the second most common complication. According to Aldrich and Harmann (1990-1991), it accounts for 10.5% of all complications in CSF shunts. The cited infection rates range from 0.17% to 14% per procedure (Welch, 1979 ; McCullough et al., 1980 ; Fibla et al., 1983 ; Walters et al., 1984 ; Shurleff et al., 1985-1986 ; Haase et al., 1987 ; Gardner et al., 1988 ; Choudhury, 1990 ; Vara-Thorbeck, 1990 ; Choux et al., 1992). In Korea it has been reported as 5.5% to 9.4% (Hu et al., 1987 ; Cho et al., 1988 ; Shin et al., 1989). According to Piatt and Carlson (1993), the risk of shunt infection by 1 year was 8.5% and the risk seemed to plateau after 27 months at 9.4%. Most shunt infections occur within 6 months, especially within 2 months after surgery (Fan-Havard and Nahata, 1987 ; Gardner et al., 1988 ; Choux et al., 1992). The present study showed a rather lower infection rate, 4.1% per procedure. As in other reports, most of the infections occurred within 2 years, more than half of them within 2 months after surgery in this series. The 2 cases whose infection presented more than 2 years after surgery had definite extrinsic sources of infection. The detailed treatment outcome of shunt infection is the subject of another study.

According to Hoppe-Hirsch et al.(1987), subdural fluid collection or hematoma formation occurred in 1.7% to 6.5% (overall 2.5% per procedure) depending on the age of the patient. However, 60% of them were asymptomatic. A literature review by Kalia et al.(1993) showed an incidence of 5% to 20%. In Korea, Cho et al.(1988) reported the incidence as 14%. In the present series, only subdural fluid collections which required drainage were counted. Subdural fluid accumulation is not a rare event, especially when the patient is older than 2 years, ventriculomegaly is chronic and severe, and the flow through the shunt can be much higher than the normal flow rate. The operated 4 cases complained of headache and the CT scans showed marked midline shift. Though there were no definite signs of intracranial hypertension, the subdural fluid was drained in the early period of this series. However, considerable amounts of subdural fluid persisted after drainages. Recently even if there is a large amount of subdural fluid collection with midline shift, the absence of definite signs of intracranial hypertension leads to conservative management. The incidence of subdural fluid accumulation which is 'absolutely' surgery-indicated may be lower than ours, 1.6%.

Other complications in the literature include migration, overdrainage syndrome, slit ventricle syndrome, isolation of a part of the ventricular system, operative intraventricular hemorrhage, seizure, secondary craniosynostosis, abdominal pseudocyst, ascites, intestinal volvulus, visceral perforation and precocious puberty (Lortat-Jacob et al., 1984 ; De-Luca et al., 1985 ; Liguori et al., 1986 ; Hislop et al., 1988 ; Choudhury, 1990 ; Hayashi et al., 1990 ; Steinbok et al., 1994). Except for migration, no other complications were the cause of shunt failure during the observation period.

An ideal shunt should drain the excessive portion of CSF without overdrainage which keeps the intracranial pressure within the physiological range and prevents collapse of the cerebral mantle. Also it should resist infection and be designed to avoid mechanical failure or obstruction. If it fails, the revision has to be easy and safe, too. Though the continuing research in this field has achieved a great deal of improvement, the ultimate goal is still far away. The various conditions of each patient at each time make the problem more complex. However, shunt survival has been getting better until recent years and is expected to improve over the coming years.

The chronological data of the present study should be considered in the planning of follow-up schedules for shunted children. Analyses of risk factors for each complication are in progress.

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