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The Contributory Factors of CSF Shunt Failure*

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= Abstract =

뇌실 복강간 단락 부전의 기여인자

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To investigate contributory factors of CSF shunt failure, 237 patients, who underwent shunt placement from January 1995 to December 1998 at our hospital, were reviewed retrospectively.

The causes of the hydrocephalus were tumor, hemorrhage, infection, congenital anomaly, normal pressure hydrocephalus, trauma and others. One hundred nine revisions of CSF shunting were done during follow up periods. The causes of shunt revisions were mechanical obstruction, malposition, infection and others. The contributory factors of CSF shunt failure and shunt survival rate were analyzed using SPSS.

The shunt survival rate at 1, 2 and 3 years after procedure was 77.1%, 75.4%, 74.1% respectively. In the young age group below 10 years old, postinfectous hydrocephalus was the most common high risk factor for shunt revision.

In conclusion, the most shunt failures developed in the first year after surgery and the age and causes of the hydrocephalus were major determinant factors of shunt revision.

KEY WORDS : Hydrocephalus · Shunt failure · Risk factor · Shunt survival.

Introduction

Hydrocephalus is one of the most common and treatable conditions encountered in neurosurgical practice and the CSF shunt is the neurosurgical procedure with the highest incidence of complications[3)4)8)9)13)14)16)18)19)]. The history of evolution of ventricular shunting for hydrocephalus is largely a history to prevent the complications of shunting[11)]. These complications can be categorized into 3 groups : "mechanical" failure related to improper function of the device, infection related to implanted foreign material, and functional failure resulting from an inadequate flow rate of functioning shunt[6)].

Efforts to reduce shunt complications are of considerable interest because these complications have significant adverse consequences. Additional operation is painful and psychologically disturbing for the patient and his or her family and from an economical point of view, each malfunction doubles the cost of the treatment.

Shunt complications are in fact more often related to some combination of factors. The importance of these factors, which may seem to be self-evident and is often taken for granted, should not be underestimated. The factors are often critical in determining the outcome of a shunt operation. In trying to reduce the rate of shunt malfunction, it is necessary to define and understand the causes and risk factors of these complications.

To investigate the contributory factors of CSF shunt failure, 237 patients, who underwent shunt placement or

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revision from January 1995 to December 1998 at our hospital, were reviewed retrospectively.

Clinical Materials and Method

1. Patient population

Patients who underwent surgery for hydrocephalus at our hospital between January 1995 and December 1998 were identified by computerized search of discharge diagnoses and procedure codes. Computed tomography and magnetic resonance image were utilized in the management of hydrocephalus throughout this interval. For each patient the following data were collected : age and sex, causes of hydrocephalus, date of the first shunt operation, date of the last follow-up, preoperative mentality, pressure and type of valve and whether external ventricular drainage was done. Patients who underwent the first shunting procedure at other hospitals were excluded. The mean age at the first shunting procedure was 45.5 years and mean follow-up period was 23.2 months.

2. Causes of hydrocephalus

The causes of hydrocephalus were hemorrhage in 103 patients(42.7%), tumor in 26(11%), infection in 17(7.2%), congenital anomaly in 19(8%), adult idiopathic in 22 (9.3%), trauma in 44(19%) and others in 6(2.5%). The age groups and causes of hydrocephalus are summarized in Table 1.

3. Definition of shunt failure

The interval from the insertion of a shunt system to revision, removal or externalization was regarded as the functioning period of shunt. Shunt failure was defined malfunction state of shunt and classified into one of the following modes : obstruction, malposition, infection, functional failure and others.

4. Analysis of factors related to shunt revision

Factors related to shunt failure have three potential origins : the surgeon, the patient, and the shunt. There are many possible risk factors related to shunt failure : attending surgeon, causes of hydrocephalus, duration of operation, time of day of operation, and whether the patient had epilepsy, young age, poor skin condition, and/or systemic infection at the time of shunting[14].

In the present study we analyzed the following factors : the age group, cause of hydrocephalus, pressure and type of valve, preoperative mentality and whether preoperative external ventricular drainage was done.

5. Statistical analysis

We performed a chi-square test using SPSS. The Kaplan-Meier curves showing shunt survival rate were figured. Statistical significance was set at a probability value less than 0.05.

Table 1. Age groups and causes of hydrocephalus

Cause \ Age	- 2	2 - 10	10 - 20	20 - 30	30 - 40	40 - 50	50 - 60	60 - 70	70 - 80	80 -	Total
Tumor	3	4	4	3	1	3	3	4	1	0	26
Hemorrhage	1	1	2	2	9	17	30	33	8	0	103
Infection	2	1	3	4	0	2	3	1	1	0	17
Congenital anomaly	11	2	1	4	0	0	0	1	0	0	19
Adult idiopathic	0	0	1	0	0	2	3	8	6	2	22
Trauma	4	1	3	7	4	4	12	8	1	0	44
Others	0	1	0	0	1	1	1	2	0	0	6
Total	21	10	14	20	15	29	52	57	17	2	237

Table 2. Revision rates according to age groups

Revision \ Age		0 - 2	2 - 10	10 - 20	20 - 30	30 - 40	40 - 50	50 - 60	60 - 70	70 - 80	80 -	Total
Revision	No.	12	3	9	10	13	20	38	48	14	2	169
(-)	%	57.1	30.0	64.3	50.0	86.7	69.0	73.1	84.2	82.4	100	71.3
Revision	No.	9	7	5	10	2	9	14	9	3	0	68
(+)	%	42.9	70.0	35.7	50.0	13.3	31.0	26.9	15.8	17.6	0	28.7
Total	No.	21	10	14	20	15	29	52	57	17	2	237

Table 3. Revision rates according to causes of hydrocephalus

Revision \ Cause		Tumor	Hm.★	Inf.★★	Cong. anomaly	Adult idiopathic	Trauma	Others	Total
Revision	No.	20	81	6	12	18	27	5	169
(-)	%	76.9	78.6	35.3	63.2	81.8	61.4	83.3	71.3
Revision	No.	6	22	11	7	4	17	1	68
(+)	%	23.1	21.4	64.7	36.8	18.2	38.6	16.7	28.7
Total	No.	26	103	17	19	22	44	6	237

Hm.★ : Hemorrahage Inf.★★ : Infection

Results

In 237 patients, 346 cases of CSF shunt placement with or without revision were done. In 68 patients, 109 cases of shunt revision were done ; once in 44 patients, twice in 12, and more than 3 times in 12. The overall shunt revision rate was 28.7%. The overall shunt survival rate at 1, 2, and 3 years after procedure was 77.1%, 75.4% and 74.1% respectively. The causes of shunt revision were obstruction (62%), infection(17%), malposition(9%), functional failure (3%) and others(9%).

The age of the patient was found to be a significant contributory factor of CSF shunt failure. The risk of CSF shunt failure was greater for patients less than 10 years of age(p=0.007). The revision rates according to age groups are summarized in Table 2. The shunt survival rate at 1 year was 61.9% in patients less than 2 years of age and 44.4% in patients ages 2 through 10.

The causes of the hydrocephalus was found to be another significant contributory factor of CSF shunt failure. Among the six most common etiolgies, shunt for normal pressure hydrocephalus had the lowest risk of shunt failure and shunt for postinfectious hydrocephalus had the highest (p=0.007). The revision rates according to causes of hydrocephalus are summarized in Table 3. And Kaplan-Meier survival curves are figured in Fig. 1.

The revision rates according to pressure and type of valve, preoperative mentality and preoperative external ventricular drainage are summarized in Table 4 to 7. But those factors had no statistically significant influence on risk of shunt failure(p-value=0.114 in pressure of valve, 0.019 in type of valve, 0.704 in preoperative mentality and 0.598 in preoperative external ventricular drainage).

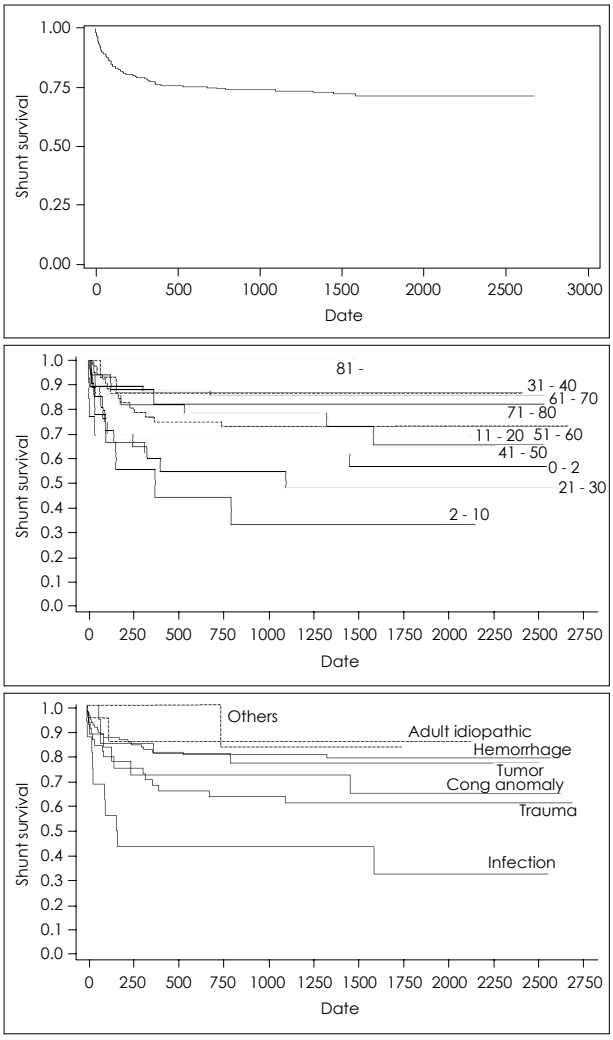

Fig. 1. Kaplan-Meier survival curves. Upper : overall shunt survival curve for 237 patients who underwent CSF shunt procedure during follow-up periods. Middle : shunt survival curves according to age groups. Lower : shunt survival curves according to causes of hydrocephalus. Survival curves were estimated using the Kaplan-Meier product-limit method.

Discussion

Hydrocephalus is a condition, not a disease, and no two hydrocephalic patients are exactly alike. Each case must be considered carefully. One should not forget that, for the patient, the best shunt is no shunt[6]. However a large number of patients still need to be shunted. In those patients, several factors need to be taken into consideration because

Table 4. Revision rates according to pressure of valve

Revision \ Pressure		Low	Medium	High	Delta	Orbis sigma	Total
Revision	No.	86	52	17	7	7	169
(-)	%	67.2	80.0	68.0	100.0	58.3	71.3
Revision	No.	42	13	8	0	5	68
(+)	%	32.8	20.0	32.0	0.0	41.7	28.7
Total	No.	128	65	25	7	12	237

Table 5. Revision rates according to type of valve

Revision \ Type		Burr-hole	Contoured	Total
Revision	No.	148	21	169
(-)	%	73.6	58.3	71.3
Revision	No.	53	15	68
(+)	%	26.4	41.7	28.7
Total	No.	201	36	237

Table 6. Revision rates according to preoperative mentality

Revision \ Mentality		Clear	Drowsy	Stupo-rous	Semico-matose	Coma-tous	Total
Revision	No.	45	74	28	20	2	169
(-)	%	63.5	74.0	75.7	71.4	100.0	71.3
Revision	No.	25	26	8	8	0	68
(+)	%	35.7	26	28.6	28.6	0.0	28.7
Total	No.	70	100	28	28	2	237

Table 7. Revision rates according to preoperative EVD

Revision \ Preoperative EVD		EVD(-)	EVD(+)	Total
Revision	No.	110	59	169
(-)	%	70.1	73.8	71.3
Revision	No.	47	21	68
(+)	%	29.9	26.3	28.7
Total	No.	157	80	237

EVD : external ventricular drainage

of their potential effect on the occurrence of shunt complications.

The risk for patient to experience a shunt failure is maximum in the first few months after surgery, ranging from 25% to 40% at one-year follow-up[5)14)16)]. Later on, after this critical period, the risk remains around 4 to 5% per year. In the present study, overall shunt failure rate at 1, 2 and 3 years after shunt procedure was 22.9%, 24.6% and 25.9% respectively.

As it is virtually impossible to determine retrospectively the actual causes of many complications, most of the reported data give only an approximation of what really happened[16)]. However, based on these data, it can be assumed that a large portion of shunt complication is shunt obstruction[16)]. In our study, obstruction was also a leading cause of shunt failure(62%). Ideally, in order to minimize the probability of obstruction, the CSF should be normal at shunt insertion. Debris can be present in the CSF after treatment of ventriculitis or after surgery involving the ventricle. Clearly, debris or blood clots in the CSF can promote obstruction of the drainage system at various levels. In these circumstances, inserting a temporary external ventricle drainage pending CSF normalization prior to inserting a shunt may reduce the risk of malfunction[13)].

On the other hand, ventriculostomy may cause CSF infection. The morbidity associated with ventriculostomy-related infection is unclear. Sundbärg, et al.[20)], identified ventriculostomy-related infection in 30 of 540 patients, all of whom recovered with no permanent symptoms or deficits related to the infection. If ventriculostomy-related infection is identified, the patient should be treated with appropriate antibiotics and ventriculostomy should be exchanged with a new one. So the question that can be raised is what is the balance between the risk of infection related to ventriculostomy and potential shunt obstruction and reoperation with its subsequent risk of infection. When is the appropriate time for shunting after external ventricular drainage? And when should the ventriculostomy be removed to avoid CSF infection? The answer may depend on patients(acuteness of hydrocephalus, severity of hemorrhage), the surgeon (training, skill, and interest) and environment(risk of infection)[17)]. In the present study, we analyzed the influence of external ventricular drainage on risk of shunt failure. In 80 of 237 patients, external ventricular drainage was done. The mean interval from external ventricular drainage to shunting procedure was 9.56 days. The revision rate was 29.9% in the group where preoperative EVD was not done and 26.3% in the group where preoperative EVD was done. But unfortunately all these data barely achieve statistical significancy demonstrating that they are inconclusive. Further careful randomized prospective studies on the influence of EVD for risk of shunt failure are necessary.

The patient less than 10 years of age had the higher risk of shunt failure than other age groups. The age of the patient was found to be a signigicant determinant of the risk of shunt failure. This may be related to immaturity of the immune system and vulnerability of the thin skin[1)7)10)15)].

Griebel, et al.[8)], reported that the underlying cause of

hydrocephalus was not a factor influencing the longevity of the shunt system. But Piatt and Carlson[14] reported that though the overall effect of etiology of hydrocephalus on estimated risk of shunt malfunction did not attain significance, trends were apparent. Among various etiologies, shunt for hydrocephalus due to tumor had the lowest risk of failure, and shunt for posthemorrhagic hydrocephalus had the highest. In the present study, shunt for hydrocephalus due to normal pressure hydrocephalus had the lowest risk of failure, and shunt for postinfectious hydrocephalus had the highest. This was significant statistically(p value =0.007).

The postinfectious hydrocephalus was caused by tuberculous meningitis(6 of 17 patients, 35.3%), bacterial meningitis(6 of 17, 35.3%) and neurocysticercosis(5 of 17, 29.4%). Shunt revision was done in all patients with hydrocephalus due to tuberculous meningitis, in 2 of 6 with hydrocephalus due to bacterial meningitis and in 3 of 6 with hydrocephalus due to neurocysticercosis. Among these postinfectious hydrocephalus, tuberculous lesions of the brain and meninges are encountered today with increasing frequency[2]. In Korea, tuberculous meningitis is a relatively common disease and without treatment invariably fatal within 4 to 6 weeks. Approximately one-quarter of patients eventually develop a thick, purulent basilar arachnoiditis with secondary hydrocephalus of either the communicating, or less commonly, the obstructive type[12]. Hydrocephalus is the most common abnormal computerized tomographic finding in tuberculous meningitis and should be treated with ventriculoperitoneal shunt whenever it is suspected to be causing clinical problems. There seems to be little risk of spreading the tuberculous infection by such a CSF diversion if the patients are simultaneously receiving antituberculous medications[2]. Even though there was no evidence of spreading the tuberculous infection after shunt procedure, significant numbers of patients showed high rates of shunt obstruction and shunt revision in the present study. The causes of shunt revision were mostly shunt obstruction(5 of 6 patients) and skin infection(1 of 6 patients). In two patients, shunt revision was done more than 3 times due to shunt obstruction. Among these patient, one patient showed a multiloculated and septated ventricular system, so 4 times of shunt revision and one third ventriculostomy was done.

Sainte-Rose, et al.[16], compared the incidence and etiology of mechanical shunt failure in a recent series of 343 patients with a flow-regulating shunt to a previous series of 1,719 patients with standard differential pressure valve. The one and 5 year shunt failure probabilities were 20.1% and 23.6%, respectively, for the flow-regulating shunt and 31.1% and 49%, respectively, for standard differential pressure valve. But in our study, there was no difference on shunt failure rate between different pressure and type of valve. Also there was no difference on shunt failure rate according to preoperative mentality.

In summary, a number of factors would interact with complexity to induce a shunt failure under different circumstances. Identifying factors related to shunt failure and a careful evaluation of the relative importance of these different factors and their mechanisms of interaction would allow preventive measures to be taken.

Conclusion

Most shunt failures developed in the first one year after shunt procedure. The following factors had no significant influence on risk of shunt failure : pressure and type of valve, preoperative mentality and whether preoperative external ventricular drainage was done. The age and causes of hydrocephalus were the most important determinants of risk of shunt failure. For this reason, it is necessary to have a careful follow-up to detect those shunt failures in the first one year after shunt procedure and especially in young age groups and patients who were shunted for hydrocephalus due to infection.

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뇌실 복강간 단락 부전의 기여인자

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= 국문초록 =

목 적 : 뇌실 복강간 단락술 부전의 기여인자를 조사 및 분석하여 뇌실 복강간 단락술의 합병증 및 재수술의 가능성을 줄이는 데에 목적이 있다.

대상 및 방법 : 1995년 1월부터 1998년 12월까지 본원에서 뇌실 복강간 단락술을 시행 받은 237명의 수두증 환자를 후향적 방법으로 고찰하여 뇌실 복강간 단락 부전의 기여인자 및 단락기 생존율을 통계학적으로 분석하였다.

결 과 : 수두증의 원인은 종양, 출혈, 감염, 선천성 기형, 정상 뇌압 수두증, 외상 등이었다. 68명의 환자에서 109회의 재수술이 이루어졌다. 재수술의 이유는 폐색, 근위부 카세타의 위치이상, 감염 등이었다. 단락기 생존율은 1년, 2년, 3년에 각각 77.1%, 75.4%, 74.1%이었다. 10세 이하의 환자에서 재수술의 빈도가 통계학적으로 의의 있게 높았다. 그리고 수두증의 원인에 따라서 통계학적으로 의의 있게 재수술의 빈도 차이가 있었다.

결 론 : 대부분의 뇌실 복강간 단락 부전은 술후 1년내에 발생하였다. 환자의 나이 및 수두증의 원인이 뇌실 복강간 단락 부전의 주요 기여인자였다.

중심 단어 : 수두증 · 단락 부전 · 위험인자 · 단락 생존.