CLINICAL RESEARCH

Spreading of Ventriculo-Peritoneal Shunt Complications Over Time: An Analysis of 210 Patients and 388 Procedures Covering a Period of Seven Years

Ventrikülo-Peritoneal Şant Komplikasyonlarının Zamana Yayılımı: Yedi Yıllık Bir Süreyi Kapsayan 210 Hasta ve 388 Cerrahi Girişimin Çözümlenmesi

PAMİR ERDİNÇLER, MEHMET YAŞAR KAYNAR, BÜLENT CANBAZ, VOLKAN ETUŞ, AHMET DİRİCAN, NEJAT ÇIPLAK, CENGİZ KUDAY

Istanbul University Cerrahpaşa Medical Faculty Departments of Neurosurgery (PE, MYK, BC, VE, NÇ, CK), and Biostatistics (AD), İstanbul, Turkey

Abstract: In this article we analyzed 210 children who were underwent shunt operation between the years 1988-1995. The causes of shunt failure in this group of patients and the spreading of these complications over time are evaluated. Shunt revisions were required in 80 of 210 patients and a total of 178 revisions were performed on these patients. Children shunted because of cerebral malformation and aqueductal stenosis were found to be more revised than other cases. The age of the patient at the shunt insertion time did not affect shunt failure. Seventynine percent of the revisions occured in 8 months following the last procedure. Proximal obstruction was the main cause of first, early, late and total revisions. The chance of having a functional shunt precluding shunt revision in the first year after first insertion of a shunt was found to be 68,4 %. Shunt infection, subcutaneous fluid collections and malposition tends to occur soon after surgery and lengthening of distal catheter, underdrainage and valve obstruction later. We conclude that time is a factor contributing to the cause of shunt failure although it is not a reliable factor in predicting the location or type of shunt failure.

Key Words: Actuarial statistic, hydrocephalus, shunt failure, ventriculoperitoneal shunt

Özet: Bu seride 1988 - 1995 tarihleri arasında şant ameliyatı olan 210 çocuk hasta, bu hastalardaki şant komplikasyonlarının sebepleri ve bu komplikasyonların zamana yayılımı incelenmiştir. Çalışma süresi boyunca 210 hastanın 80'inde şant revizyonu gerekti ve bu hastalara toplam 178 ameliyat yapıldı. Beyin malformasyonu ve akuadukt stenozu nedeni ile şant takılan çocuklarda revizyon oranı diğer olgulardan daha fazla bulundu, buna karşılık şant takıldığında hastanın yaşı ile şant malfonksiyonu arasında bir ilişki bulunamadı. Revizyonların % 79'u bir önceki ameliyattan sonraki 8 ay içerisinde yapıldı. Proksimal tıkanma erken, geç ve toplam revizyonların en sık sebebiydi. İlk şant takılmasından sonraki birinci yılda şant revizyonu gerektirmeme olasılığı % 68,4 olarak bulundu. Şant enfeksiyonu, cilt altına sıvı toplanması ve kötü yerleştirme cerrahiden sonra erken dönemde, distal kateter uzatılması, yetersiz drenaj ve valvin tıkanması ise daha geç dönemlerde ortaya çıkmaya eğilim gösteriyordu. Sonuç olarak zamanın şant komplikasyonuna etki eden bir faktör olduğuna, ancak şant komplikasyonunun yerini ve tipini belirlemede güvenilir olmadığına karar verildi.

Anahtar Sözcükler: Aktuaryel istatistik, hidrosefali, şant komplikasyonu, ventrikülo-peritoneal şant

INTRODUCTION

Efforts to reduce shunt complications are of considerable interest because these complications have significant adverse consequences. Clinically, there is a low but real percentage of death or neurological impairment related to shunt complications. It is also a painful and psychologically disturbing additional operation for the patient and his or her family. Finally, from an economic point of view, each malfunction doubles the cost of the treatment.

Complications in cerebrospinal fluid (CSF) shunting have received considerable attention and many articles have been written about them. In trying to reduce the rate of shunt malfunction, it is necessary to define and understand the causes of these complications. Factors related to shunt failure have three potential origins: the surgeon, the patient, and the shunt. Shunt complications are in fact more often related to some combination of factors. Recently, time is proposed as a factor in determining the site or type of shunt failure (9). Piatt (14) suggested that the causes of shunt failure are different during the early and the late periods.

The purpose of this article is to study our experience with CSF shunt failure thoroughly as a function of time.

PATIENTS AND METHODS

Clinical records of 210 consecutive patients under 15-year of age, which underwent ventriculoperitoneal (VP) shunt insertion between January 1988 and December 1995 in the Department of Neurosurgery of Cerrahpaşa Medical School were reviewed. Patients with another CSF diversion modalities or with multiple ventricular catheter due to multiloculated hydrocephalus were excluded. In all patients, the ventricular catheter was inserted via posterior parietal burr hole. The peritoneum was opened via a subcostal incision except a few cases in which a midline substernal incision was used. All patients received a Pudenz-Schulte shunt system (PS Medical) with few exceptions. The medium-pressure version was inserted except for newborns in whom a low-pressure version was used.

Shunt revisions were required in 80 of the 210 patients and a total of 178 revision operations were performed for these patients during the study period. A CSF shunt was considered to have failed, if and only if it required reoperation. Because no CSF shunt infections were treated with antibiotics alone during the accrual period, this definition includes both mechanical and infectious modes of failure. Infection was listed as present if CSF cultures were positive; in that event, all shunts were removed.

The data were analyzed by descriptive statistical methods. The survival of simple, linear CSF shunts were analyzed with commercially available software utilizing life table techniques.

RESULTS

Fiftyfour percent of the patients were infants (under 1 year of age) and 45 cases were newborns (0-2 month) (Table I). There were 108 boys versus 102 girls. Meningomyelocele, neoplasm and meningitis were the main causes of hydrocephalus. Germinal matrix hemorrhage of the preterm infants were the cause of hydrocephalus in only 2 % of the patients (Table II).

One hundred thirty children (62 %) were free of revision and the rest 80 children (38 %) underwent a total of 178 revision procedures. Children shunted

Table I: Age Distribution of Patients.

Age	n	%	Revised	% *
0-2 month	45	21,4	20	44,4
2-12 month	68	32,4	25	36,7
1-2 year	15	7,1	6	40
2-5 year	28	13,4	7	25
5-10 year	38	18,1	16	42,1
10-15 year	16	7,6	6	37,5
Total	210	100	80	38

* % shows ratio of revised children to total in age subgroups

Table II: Causes of Hydrocephalus as to Number and Percentage of Revised Patients.

Cause	n	Revised	%
Meningomyelocele	74	23	31
Neoplasm	54	19	35
Meningitis	34	13	38
Cerebral malformation	22	11	50
Aqueductal stenosis	22	13	59
Post hemorrhagic	4	1	25
Total	210	80	38

because of cerebral malformation, such as Dandy-Walker syndrome and aqueductal stenosis were found to have more revisions than the rest of cases (Table II). However, when different age groups were analyzed, revision rate did not show significant difference between subgroups (Table I).

Seventy nine percent of the revisions occurred in 8 months following the previous procedure. Proximal obstruction was the main cause of first, early, late and total revisions. Shunt infections, proximal and distal complications, and overdrainage constituted 78,6 % of all revisions procedures (Table III). Shunt infection was the cause of first revision in 19 % of patients. In infant group (under 1 year of age), this rate was 20 %. Overall rate of shunt infection in this series of 388 procedures was 9 % per procedure.

Table III: Causes of First, Early and Late Revisions.

	First revision	Early (<8 month)	Late (>8 month)	Total
Proximal obstruction	28 (35%)	37 (26%)	13 (35%)	50
Distal obstruction	13 (16%)	29 (20,5%)	6 (16%)	35
Infection	15 (19%)	34 (24%)	1 (3%)	35
Overdrainage	9 (11%)	17 (12%)	3 (8%)	20
Malposition	5 (6%)	13 (9%)	1 (3%)	14
Underdrainage	5 (6%)	3 (2%)	3 (11%)	7
Valve obstruction	4 (5%)	3 (2%)	3 (8%)	6
Subcutaneous fluid collections	1 (1%)	5 (3,5%)	0 (3%)	6
Lengthening of distal catheter	0	0 (0%)	5 (13%)	5
Total	80	141	37	178

Actuarial graph showed that the risk for a patient to experience a shunt failure was maximum in the first few months after surgery, and 31,6 % at one year follow-up (Figure 1). Later on, after this critical period, the risk remains around 1 % to 7 % per year. An analysis of the time of occurrence of each type of complication and distribution over the follow-up showed that shunt infection, subcutaneous fluid collection and malposition tends to occur soon after surgery and lengthening of distal catheter, underdrainage and valve obstruction later (Figure 2).

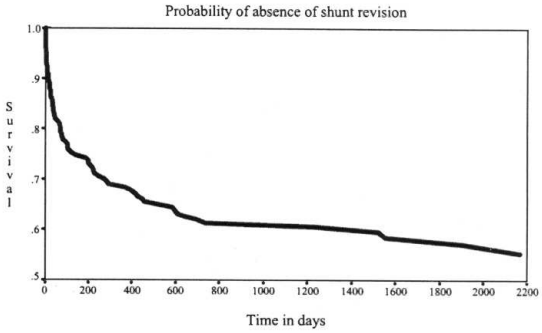

Figure 1: Survival function of our patients treated with ventriculoperitoneal shunts. The cumulative proportion of shunts not revised (that "survived") is represented by the Y axis. The X axis is the length of follow-up (in days) after the first shunt insertion.

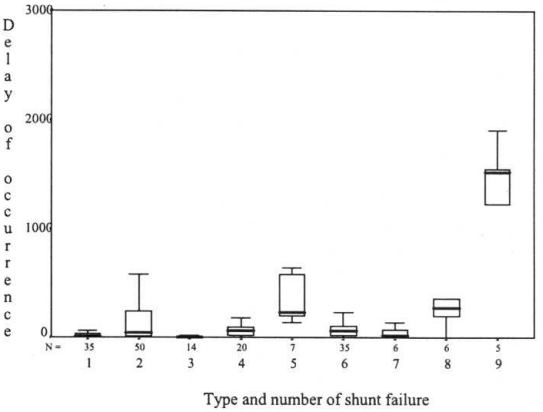

Figure 2: Multiple box and wisker plot of delay of occurrence of shunt complications (days) versus type of complications. The central box covers the middle 50% of the data values, between the lower and the upper quartile; the "wiskers" extend out to the extremes, while the central line is at the median. The shunt complications are codified as follows: 1- infection; 2- proximal obstruction; 3- malposition; 4- overdrainage; 5- underdrainage; 6- Distal obstruction; 7- subcutaneous fluid collection; 8- valve obstruction; 9- lengthening of distal catheter. The number over each code represents the total number of this particular complication.

DISCUSSION

Shunt complications are numerous (15,17,18). To quote McLaurin et al. (11), it can be said that "the history of the evolution of ventricular shunting for hydrocephalus is largely a history to prevent the complications". Definition of a shunt failure is not easy, and the literature is often quite confusing. While

problems directly related to the shunt (e.g., proximal obstruction) are universally acknowledged as shunt complications, problems related to imperfect shunt function (e.g., subdural collection) are sometimes more difficult to interpret (1,12). Finally, some shunts are inserted with deliberate plans to revise, i.e. lengthen the peritoneal catheter or upgrade the valve, at some time in the future. In this study, we accepted in terms of imperfect shunt function any problem that required a subsequent operation.

The major underlying cause of hydrocephalus in our patients were meningomyelocele, neoplasm and meningitis. Kast et al. (9) founded no correlation between the etiology of hydrocephalus and shunt malfunction. In our analysis, cerebral malformation and aqueductal stenosis seem to increase the risk of CSF shunt failure. These children with congenital hydrocephalus have generally an important differential pressure gradient between supra- and infratentorial compartments, and grossly affected CSF circulation pathways (7,10). Thus, insertion of a shunt can disturb the hydrodynamic process of CSF, causing a trapped fourth ventricle or inadequate drainage or upward herniation, and CSF shunt failure occurs.

Piatt and Carlson (15) reported that the most important determinant of shunt failure was the age of the patient. In many series, shunt infections are reported to occur more often in infants than in young children (2,16). We have not found any significant correlation between the age of the patients and CSF shunt failure or shunt infection. These statistical remarks may be due to the absence of a follow-up in this age group of patient. Children shunted under 1 year of age are generally prone to the multiple systemic complications such as malnutrition, pulmonary infection or electrolyte imbalance, each of which is fatal when untreated. In the majority of these infants, the underlying cause of hydrocephalus was myelomeningocele, thus, complications due to the Chiari II malformation are also evident. In our opinion, because of economic, cultural and social factors the families of these infants did not bring them back after the first surgery even if serious complications occurred.

Our survival analysis graph showed that shunt complications continue to occur, but the risk is maximum in the first year after surgery. In different series of shunted patients (3,15,17), the risk for a patient to experience a shunt failure ranged from 25 % to 40 % at one-year follow-up. Similarly, this probability has been 31,6 % in our series. Some types of shunt failure tend to occur soon after surgery and some later. In a recent series by Kast et al. (9), 70 % of proximal shunt failures occurred within 2 years of the last placement or revision and 80 % of distal failures occurred after 2 years or more. This was not the same in our series. Proximal failures, either in the late or early period, were the most common causes of shunt failure as in many series (11,17,18). In our analysis, shunt infection, malposition and subcutaneous fluid collections appeared as complications of the early period and lengthening of distal catheter, underdrainage or valve obstruction as complications of the late period. For a particular type of shunt failure, the causative factors are frequently not the same over time. For example, the ventricular catheter can be occluded soon after the surgery by a ventricular clot and later by the choroid plexus. Some distal failures in the early period may be due to the low-grade infections that remain undiagnosed, causing malinterpretation of failure in the early period (4,5,13). Piatt et al. (14) suggested that the causes of shunt failure that occurred within 8 months from the previous operation are different than that occurred after 8 months. In the late period, some provocative effects such as minor trauma, viral infections or other inflammatory or immune reactions disturb the marginally compensated patient in which a partially occluded or imperfectly positioned CSF shunt provide just enough drainage to prevent symptoms. Overdrainage is a typical example for Piatt et al.'s suggestion (14). Overdrainage is a constant problem with the existing valves. As the overdrainage phenomenon is partly related to the postural changes and the patient height, this risk is highest in the older patient. This complication represents less than 10 % of the shunt failures in pediatric series and about 30 % in adult series (8). In our series, 11,2 % of revisions occurred because of overdrainage symptoms of which the majority occurred in the early period. Overdrainage also highly correlates with ventricular catheter obstruction. Occurrence of slit ventricle will promote obstruction of the ventricular catheter. We suggest that overdrainage symptoms which occur in the late period may be secondary to some provocative effects suggested by Piatt et al. (14), those which occur in the early period are true overdrainage such as subdural collection or obstruction of the ventricular catheter because of slit ventricle.

Underdrainage is a problem especially occurring in new-born babies. Five of the 7 revisions

because of underdrainage were first revisions, but they appeared usually later after a follow-up period. In these cases, low or low-low pressure valve must be chosen to avoid this complication. Valve obstruction occurs under three different circumstances: 1) At shunt insertion time, there is always a risk of contamination of the valve with clot or parenchymal tissue or other debris from the ventricular catheter; 2) bacterial proliferation in a shunt system can first appear as a valve occlusion in the early period (19), 3) cellular immune reactions, as suggested in well-documented cases of sterile shunt malfunctions, may lead to late valve obstruction (6). Although improper placement is an avoidable complication, it remains unacceptably high in our series. Careful surgical technique is probably the best solution for proper catheter placement. It is a typical complication of the early period. Finally, subcutaneous accumulation of CSF is usually due to shunt obstruction or technical errors and appears in the early period.

Shunt complications are inevitable, but delaying shunt malfunction as long as possible with the application of careful neurosurgical technique is a realistic goal. Time is a factor contributing to the cause of a shunt failure, but it is not a reliable factor in predicting the location or type of the shunt failure. In fact, in shunt surgery many factors such as time, patient's age, techniques, surgeons, shunt design, CSF characteristics and patients characteristics play a role. Knowledge of tendency of some type of a shunt failures to occur in the early or in the late period may help to better understand the underlying mechanisms of CSF shunt failure.

Correspondence: Pamir Erdinçler
PK 19
34312 K.M.Paşa
İstanbul Turkey
Phone : (212) 588 48 00
Fax : (212) 632 00 26

REFERENCES

1. Abbott R, Epstein FJ, Wisoff JH: Chronic headache associated with with a functioning shunt: uselfulness of pressure monitoring. Neurosurgery 28:72-77, 1991
2. Ammirati M, Raimondi AJ: Cerebrospinal fluid shunt infections in children. A study on the relationship between the etiology of hydrocephalus, age at the time of shunt placement, and infection rate. Child's Nerv Syst 3:106-109, 1987
3. Bierbrauer KS, Storrs BB, McLone DG, Tomita T, Dauser R: A prospective randomized study of shunt function and infections as a function of shunt placement. Pediatr Neurosurg 16:287-291, 1990-91
4. Burchianti M: Peritoneal cerebrospinal fluid pseudocysts: A complication of ventriculoperitoneal shunts. Child's Nerv Syst 4:286-289, 1988
5. Camarata PJ, McGeachie RE, Haines SJ: Dorsal midbrain encephalitis caused by propionibacterium acnes. J Neurosurg 72:654-658, 1990
6. Gower DJ, Lewis JC, Kelly DI: Sterile shunt malfunction. A scanning electron microscopic perspective. J Neurosurg 61:1079-1084, 1984
7. Hirsch JF, Pierre-Kahn A, Renier D: The Dandy-Walker malformation. A review of 40 cases. J Neurosurg 61:515-522, 1984
8. Hoppe-Hirsch E, Sainte-Rose C, Renier D: Pericerebral collections after shunting. Child's Nerv Syst 3:97-102, 1987
9. Kast J, Duong D, Nowzari F, Chadduck WM, Schiff SJ: Time-related patterns of ventricular shunt failure. Child's Nerv Syst 10:524-528, 1994
10. Lourie H, Shende MC, Krawchenko J, Steward OH: Trapped fourth ventricle as delayed complication of ventricular shunting. Report of two unusual cases. Neurosurgery 7:279-282, 1980
11. McLaurin RL: Ventricular shunts: complications and results, in Wonsiewicz M (ed), Pediatric Neurosurgery: Surgery of the Developing Nervous System, Philadelphia: WB Saunders, 1989:219-229
12. Nowak TP, James HE: Migraine headaches in hydrocephalic children: a diagnosis dilemma. Child's Nerv Syst 5:310-314, 1989
13. Parry SW, Schuhmacher JF, Llewellyn RC: Abdominal pseudocysts and ascites formation after ventriculoperitomeal shunt procedures: Report of four cases. J Neurosurg 43:476-480, 1975
14. Piatt JH Jr: Cerebrospinal fluid shunt failure: Late is different from early. Pediatr Neurosurg 23:133-139, 1995
15. Piatt JH Jr, Carlson CV: A search for determinants of cerebrospinal fluid shunt survival: Retrospective analysis of a 14-year institutional experience. Pediatr Neurosurg 19:233-242, 1993
16. Pople IK, Bayston R, Hayward RD: Infection of cerebrospinal fluid shunts in infants: A study of etiological factors. J Neurosurg 77:29-35, 1992
17. Sainte-Rose C, Piatt JH Jr, Renier D: Mechanical complications in shunts. Pediatr Neurosurg 17:2-9, 1991-92
18. Sayers MP: Shunt complications. Clin Neurosurg 28:393-400, 1976
19. Walters BL, Hoffman HJ, Hendrick EB: Cerebrospinal fluid shunt infections. Influences on initial management and subsequent outcome. J Neurosurg 60:1014-1021, 1984