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VENTRICULOPERITONEAL SHUNT INFECTIONS IN PEDIATRIC PATIENTS ADMITTED AT THE UP-PGH FROM 1999-2001: CLINICAL PROFILE AND PREDISPOSING FACTORS

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ABSTRACT

Objectives: To describe the clinical profile of pediatric patients with ventriculoperitoneal shunt infection, determine its incidence, identify predictive factors and identify the common organisms causing shunt infections.

Design: Case Control Study

Setting: Tertiary hospital

Subjects: Medical records of pediatric patients, less than 19 years of age, who underwent ventriculoperitoneal shunting from January 1999 to December 2001 were reviewed as to the incidence of shunt infection, the clinical profile and possible risk factors predisposing to shunt infection. A total of 130 pediatric patients who underwent ventriculoperitoneal shunting were included in this study. The criteria by Meirovitch[1], et al were used for the diagnosis of shunt infection. Predictive factors were analyzed by Chi square and Logit analysis.

Results: Of the 130 pediatric patients who underwent ventriculoperitoneal shunting which were included in this study, 20 patients developed shunt infection. Twenty-seven episodes developed in 20 patients. The infection rate was 15.4%/operative procedure and 20.8%/patient. Six patients (30%) of the initially infected patients had more than one infectious episode. Predominating pathogens in patients included *Stapylococcus aureus* (14.8%), *Klebsiella sp.* (14.8%), *Acinetobacter sp.* (14.8%) and *Staphylococcus epidermidis* (11.1%). Fever was the predominant clinical presentation, followed by local signs of infection (erythema, presence of pus/discharge, abscess formation), meningitic symptoms, and symptoms of peritoneal irritation. Management included both medical and surgical treatment in all cases. The most common method was the use of antibiotics together with external ventricular drainage; shunt removal and reinsertion of a new shunt. Risk factors for development of shunt infection identified in this study significant at 95% CI included the operating room used, presence of shunt revision, and the length of hospital stay at the time of shunting.

Conclusion: There is a higher rate of infection per operative procedure in PGH from 1999 to 2001 at 15.4%, compared to those in 1993 to 1995 (11.8%). Etiologic agents differed from foreign literature with *S. aureus* and gram negative organisms being the predominant organisms. Predisposing risk factors which showed significant correlation to the rate of shunt infection include the operating room used, a previous shunt revision and the length of hospital admission at the time of shunting.

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Keywords: Ventriculo peritoneal shunt infections, pediatric shunt infections

INTRODUCTION

Soon after cerebrospinal fluid (CSF) shunts became available in the late 1950s, infection was recognized as a serious complication of their use. Infection is a serious, but common complication of shunts procedures and is associated with high morbidity and mortality. The rate of shunt infection according to various authors range from 3% to 29% and mortality rate ranges from 34% to 40%. Most shunt infections occur within 2 months of shunt insertion while 80% will present within 3 months and 90% within 6 months.

Most infections are caused by *S. epidermidis* (40%), followed by *S. aureus* (20%). The remainder of shunt infections is caused by a variety of organisms including Streptococci, aerobic gram-negative rods, enterococci, and yeasts.[1,2,3,4] In most shunt infections the organism is spread to the surgical wound either directly from the adjacent skin or by gloves and instruments contaminated with the patients flora. Pople et al showed that the density of pre-op skin bacteria was significantly higher in those patients who developed shunt infection.[5] In late infections, when the organism is a gram negative, an underlying condition (bowel erosion, skin breakdown, etc.) should be sought.

Early recognition of shunt infection poses a challenge to clinicians. Clinical presentation is most often nonspecific and in 31.7% of cases, no major sign or symptom had pointed to the shunt as the cause of the illness. Moreover, CSF studies may initially be normal on microscopy and biochemistry and that multiple CSF samples taken from various sites are sometimes needed before a pathogen can be isolated.

Management has been a subject of research over the years but still no single treatment strategy is universally

accepted at the present time. Success was reported in 64% of infections using systemic and intraventricular antibiotics without surgery. However, James et al in their randomized prospective trial of treatment of CSF shunt infections favored surgical treatment rather than use of antibiotics alone.[6] Gardner et al, and Walters et al, suggested that the best treatment for shunt infection consisted of shunt removal, EVD (external ventricular drainage), administration of antibiotics and shunt replacement by a new shunt system only after recovery.[7,8]

REVIEW OF LITERATURE:

Postoperative infections are major complications of cerebrospinal fluid (CSF) shunting in the treatment of hydrocephalus and other conditions with obstructed CSF circulation. In a retrospective study by Borgbjerg et al of first-time shunted patients with hydrocephalus operated on in the years 1958-1989 (special reference to the infection rate and to the influence of the following variables: time period, age of the patient, education of the neurosurgeon, length and time of the operation and the exact placement of the distal drain), the overall infection rate for all implanted CSF shunts was 7.4% (5.7-9.3%) and the acute rate of infection was 6.2% (4.6-7.9%).[2] The rate of infection was virtually constant for all variables with the exception of the education of the neurosurgeon. Neurosurgical trainees particularly had a significantly higher rate of infection.

Innovations in shunt technology and neuroendoscopy have been increasingly applied to shunt management. However, the relative life span of shunts and the etiology of shunt failure have not been characterized. Mc Girt et al showed that increasing number of shunt revisions, decreasing patient age in years, gestational age <40 weeks but not the etiology of hydrocephalus were associated with an increased risk of shunt failure. Revisions versus primary placements, Dandy-Walker cysts and gestational age <40 weeks were independently associated with proximal, distal and infectious causes of failure, respectively.[9]

Repeated CSF shunt failures in pediatric patients are common, and they are a significant cause of morbidity and, occasionally, of death. To date, the risk factors for repeated failure have not been established. Tuli, Drake et al showed that failure time from the first shunt procedure was an important predictor for the second and third episodes of failure, thus establishing an association between the times to failure within individual patients.[10] An age younger than 40 weeks gestation at the time of the first shunt implantation carried a hazard ratio of 2.49 for the first failure, which remained high for subsequent episodes of failure. An age from 40 weeks gestation to 1 year (at the time of the initial surgery) also proved to be an important predictor of first shunts malfunctions. The cause of hydrocephalus was also significantly associated with the risk of initial failure and, to a lesser extent, later failures. Other concurrent surgical procedures were associated with an increased risk of failure.

The value of antibiotic prophylaxis for clean neurosurgical procedures without the implantation of a foreign body has been conclusively demonstrated. Attempts to confirm its efficacy for cerebrospinal fluid shunt operations have produced confusing and inconclusive results. A metanalysis by Haines and Walters suggest a statistically significant effect favoring antibiotic prophylaxis (approximately a 50% reduction in infection risk when antibiotic prophylaxis is used). The effect is strongly related to the baseline infection rate when prophylaxis is not used and disappears when the baseline infection rate is at or below about 5%.[11]

In the Philippines, shunt infection still remains to be a major complication of shunt insertions. A study conducted by Amante et al in 1995 showed an infection rate of 11.8% per operative procedure in PGH, with a median time to onset of shunt infection after surgery of 40 days. Common infecting organisms were *Stapylococcus*(45.8%) followed by *Klebsiella*(12.5%). Correlation was noted between shunt infection and poor nutritional status, presence of associated foci of infection at the time of surgery, type of shunt used, the number of shunt revisions and the presence of post-operative CSF leak and dehiscence.[12]

General Objective:

To describe the clinical profile of pediatric patients with ventriculoperitoneal shunt infection and determine its incidence in UP-PGH from January 1999 to December 2001.

Specific Objective:

1. To identify predictive factors that may predispose to shunt infection.
2. To identify the common organisms causing shunt infections.

METHODOLOGY:

All patients below 19 years admitted at the Philippine General Hospital from January 1999 to December 2001 who underwent ventriculoperitoneal shunting were included in this study.

The following criteria by Meirovitch[1], et al were used for the diagnosis of shunt infection:

Clinical:

1. Meningeal or peritoneal signs in the presence of a shunt.
2. Signs of infection along the shunt tract.
3. Shunt malfunction in combination with any of the above.
4. Fever > 38°C in combination of any of the above, with exclusion of another site of infection.

Laboratory:

1. Positive bacterial culture of either CSF, blood, shunts insertion site, wound or any combination of these.
2. CSF pleocytosis of > 11 cells/cu mm or CSF protein > 100 mg/dl (0.1 g/L) or CSF glucose < 10 mg/dl (0.56 mmol/L).

Diagnosis of shunt infection was made if either of the two criteria is fulfilled:

I. Positive culture +/- one clinical criterion
II. In the absence of a positive culture, at least any three of the above categories

Charts of the patients who underwent ventriculoperitoneal shunting from January 1999 to December 2001 were reviewed and those diagnosed to have shunt infection based on the above criteria were analyzed with regard to the following: 1) clinical presentation; 2) CSF characteristics; 3) bacteriologic features; and 4) management.

Exclusion criteria for the study included:

1. Patients who underwent tube ventriculostomy (Use of nasogastric tube/NGT for ventriculoperitoneal shunting).
2. Concomitant bacterial CNS infection at the time of ventriculoperitoneal shunting

Factors previously known or suspected to predispose to ventriculoperitoneal shunt infection such as age, sex, nutritional status of the patient (based on weight percentiles according to the National Center for Health Statistics 2000), etiology of hydrocephalus, diagnostic and neurosurgical procedures done prior to VP shunting, associated foci of infection at the time of surgery, composition of surgical team, OR room used (RCB and LCB), ward located (Wards 6, 9, 11, and Pay) length of hospital stay, and prophylactic antibiotics used were identified in all the patients who underwent VP shunting. These variables were analyzed and correlated with the occurrence of shunt infection using chi square, odds ratio and Logit analysis.

RESULTS:

A total of 130 pediatric patients who underwent primary ventriculoperitoneal shunting at UP-PGH were identified during the 3-year period of study (1999-2001), with 20 patients developing shunt infection based on the criteria set by Meirovitch, et al. Eighteen patients had positive CSF cultures, 6 of who also had positive blood cultures. Two cases had negative CSF cultures but had CSF pleocytosis, hypoglycorrachia or increased CSF protein, and fulfilled 3 clinical criteria. Twenty-seven episodes of shunt infection developed in 20 patients. The estimated infection rate was 15.4%/operative procedure and 20.8%/patient. Of the patients with shunt infection, 12 were male (60%) and 8 were female (40%) with ages ranging from 21 days to 7 years at the time of shunting (mean of 32 months). The time of onset from the shunting procedure to the onset of the first symptom of shunt infection ranged from 14 days to 3 years (mean of 8 months). The etiologies of hydrocephalous for the patients with shunt infection are shown in Table1.

Table 1. Etiology of hydrocephalus in 20 patients with shunt infection

Cause of Hydrocephalus	Number of Cases	Percentage (%)
Congenital	12	60
Aqueductal stenosis		
Nasocthmoidal	8	
Meningocoele	3	
Dandywalker	1	
Tumor	2	10
Infection	5	25
TB Meningitis	3	
Post-Meningitic	2	
Vascular	1	5
TOTAL	20	100

Table 2 shows the clinical presentation of the patients with shunt infection. Fever was the predominant clinical presentation, followed by local signs of infection (such as erythema, presence of pus/discharge, abscess formation), meningitic symptoms, and symptoms of peritoneal irritation. Fourteen (70%) of the cases are proximal infections while 6 cases (30%) were distal infections.

Table 2. Clinical presentation of 20 patients with shunt infection

Clinical Presentation	Number of cases	Percentage (%)
Fever	17	85
Local signs of infection (erythema, discharge, abscess)	14	70
Altered sensorium	7	35
Vomiting	7	35
Dehiscence	3	15
Seizures	2	10
Irritability	2	10
Abdominal distension	2	10
Shunt migration	2	10
Neck rigidity	2	10
Abdominal pain	1	5

The most common pathogens isolated from the shunt infections were *Staphylococcus aureus, Acinetobacter sp,* and *Klebsiella sp,* with an infection rate of 14.8% each, followed by *Staphylococcus epidermidis* with an infection rate of 11.1% (Table 3). Six patients (30%) had at least 2 episodes of shunt infections, 1 patient with candidemia grew *Candida sp* in the CSF, and no organisms were isolated in 2 patients (5%).

Table 3. Pathogens isolated in shunt infections

Organism Isolated	Number of cases	Percentage (%)
Staphylococcus aureus	4	14.8
Acinetobacter sp.	4	14.8
Klebsiella sp.	4	14.8
Staphylococcus epidermidis	3	11.1
Enterobacter cloacae	2	7.4
Alkaligenes faecalis	2	7.4
Hafnia alvei	2	7.4
No growth	2	7.4
Pseudomonas putida	1	3.7
Escherichia coli	1	3.7
Enterococcus sp.	1	3.7
Candida sp.	1	3.7

Antimicrobial sensitivities were determined by the Kirby-Bauer Disk Diffusion method. Table 4 shows the antimicrobial sensitivities of the top 5 microbial isolates. Notable are the resistance of *Staphylococcus sp* to Oxacillin, and most of the top isolates to broad-spectrum antibiotics such as the third and fourth generation cephalosporins and Meropenem.

Table 4. Antimicrobial Sensitivity of the top 5 microbial isolates (number of cases and percentage of sinsitive organism).

Organism Isolated	Pen G	Chlo	Ceft	Cefx	Cep	Mer	Amk	Oxa	Van
Staphylococcus aureus	1 25%	2 50%	0	0	0	0	0	2 50%	1 25%
Acinetobacter sp.	0	1 25%	1 25%	0	1 25%	2 50%	0	0	0
Klebsiella sp.	1 25%	0	2 50%	1 25%	3 75%	2 50%	2 50%	0	0
Staphylococcus epidermidis	1 33%	0	0	0	0	0	0	1 33%	2 67%
Enterobacter cloacae	0	0	1 50%	1 50%	2 100%	1 50%	2 100%	0	0
Alkaligenes faecalis	0	0	2 100%	0	0	2 100%	0	0	0
Hafnia alvei	0	0	1 50%	0	1 50%	1 50%	1 50%	0	0

Pen G – Penicillin G
Chlo – Chloramphenicol
Ceft – Ceftazidime
Cefx – Ceftriaxone
Cef – Cefepime
Mer – Meropenem
Amk – Amikacin
Oxa – Oxacillin
Van – Vancomycin
0 – Not tested or resistant

Management

All the 20 cases of shunt infections were managed by a combination of medical and surgical treatment. Combinations of at least 2 intravenous antibiotics were used in all cases, which were given from 3 to 6 weeks. No intraventricular antibiotics were used in this study. Antibiotics used include the following: Oxacillin, Cotrimoxazole, Ceftriaxone, Ceftazidime, Cefepime, Amikacin, Netilmycin, Vancomycin, Imipenem, Meropenem, Metronidazole, and Ciprofloxacin. In one case were the isolated pathogen was *Candida sp*, Amphotericin B was given for 20 days. Aside from the intravenous antibiotics, quadruple anti-TB medications were given to patients diagnosed with TB meningitis, which consisted of Isoniazid, Rifampicin, Pyrazinamide and Streptomycin.

Surgical treatment included external ventricular drainage in 11 cases (55%), tube ventriculostomy in 4 cases (20%) and Omaya shunting in 1 case (5%). Shunt removal was done at one point in all cases (100%) of shunt infections.

Possible Predisposing factors in Shunt Infections

Table 5. Results of the chi-square test and odds ratio to determine the dependence between age and sex and the development of shunt infection in pediatric patients at PGH from January 1999 to December 2001.

Factor	w/ shunt infection	w/o shunt infection	Total	*p* Value	Odds ratio
Age					
< 6 months	3(15%)	31(28%)	34	0.3	0.450
> 6 months	17(85%)	79(72%)	96	38	(0.123, 1.643)
Sex					
Male	12(60%)	60(54%)	72	0.8	1.25
Female	8(40%)	50(46%)	58	36	(0.474, 3.298)

Table 6. Results of the Chi-square test and odds ratio to determine the dependence between the etiology of hydrocephalus and the development of shunt infection in pediatric patients at PGH from January 1999 to December 2001.

Factor	w/ shunt infection	w/o shunt infection	Total	*p* Value	Odds ratio
Infectious	5(25%)	37(34%)	42	0.617	0.658
No Infectious	15(75%)	73(66%)	88		(0.222,1.950)

The etiology of hydrocephalus, whether infectious or non-infectious, had no significant statistical correlation to the rate of shunt infection.

Table 7. Results of the Chi-square test and odds ratio to determine the dependence between a concomitant infection and the development of shunt infection in pediatric patients at PGH from January 1999 to December 2001.

Factor	w/ shunt infection	w/o shunt infection	Total	*p* Value	Odds ratio
Concomitant Infection	8(40%)	22(20%)	30	0.096	2.66 (0.960, 7.316)
No Infection	12(60%)	88(80%)	100		

The presence of a concomitant infection (pneumonia, sepsis, urinary tract infection, etc.) in patients had a significant statistical relationship to shunt infection only at the 90% confidence interval. There was no significant correlation in both Chi-square and Odds ratio at 95% CI.

Table 8. Results of the Chi-square test and odds ratio to determine the dependence between the neurosurgeon and the development of shunt infection in pediatric patients at PGH from January 1999 to December 2001.

Factor	w/ shunt infection	w/o shunt infection	Total	*p* Value	Odds ratio
Consultant	2(10%)	12(11%)	14	0.786	0.91
Resident	18(90%)	98(89%)	116		(0.187, 4.401)

The composition of the neurosurgical team had no statistical significance to the rate of shunt infection.

Table 9. Results of the Chi-square test and odds ratio to determine the dependence between the operating room and the development of shunt infection in pediatric patients at PGH from January 1999 to December 2001.

Factor	w/ shunt infection	w/o shunt infection	Total	*p* Value	Odds ratio
RCB	4(20%)	64(58%)	68	0.004	5.57
LCB	16(80%)	46(42%)	62		(1.746, 17.741)

RCB – right central block LCB – left central block

Significant statistical relationship to the rate of shunt infection was observed when the operation was conducted at the left central block, with a 5.57 odds ratio.

Table 10. Results of the Chi-square test and odds ratio to determine the dependence between the presence of previous surgical procedures and the development of shunt infection in pediatric patients at PGH from January 1999 to December 2001.

Factor	w/ shunt infection	w/o shunt infection	Total	*p* Value	Odds ratio
Previous surgery	5(25%)	20(18%)	25	0.687	1.5 (0.488, 4.607)
None	15(75%)	90(82%)	105		

No significant statistical relationship was noted between the previous surgical procedures to the rate of shunt infection.

Table 11. Results of the Chi-square test and odds ratio to determine the dependence between the presence of previous diagnostic procedures (<1 month) and the development of shunt infection in pediatric patients at PGH from January 1999 to December 2001.

Factor	w/ shunt infection	w/o shunt infection	Total	*p* Value	Odds ratio
Previous diagnostics	14(70%)	60(55%)	74	0.299	1.944 (696, 5.432)
None	6(30%)	50(45%)	56		

There was no statistical association between prior diagnostic procedures (lumbar puncture, shunt tap) to the rate of shunt infection.

Table 12. Results of the Chi-square test and odds ratio to determine the dependence between the shunt revisions and the development of shunt infection in pediatric patients at PGH from January 1999 to December 2001.

Factor	w/ shunt infection	w/o shunt infection	Total	*p* Value	Odds ratio
Shunt revision	7(54%)	9(8%)	16	0.003	6.03 (1.924,18.974)
None	13(46%)	101(102%)	114		

Shunt revisions in patients with ventriculoperitoneal shunts were significantly related to the rate of shunt infection.

Table 13. Results of the Chi-square test and odds ratio to determine the dependence between the ward the patient was admitted and the development of shunt infection in pediatric patients at PGH from January 1999 to December 2001.

Factor	w/ shunt infection	w/o shunt infection	Total	*p* Value	Odds ratio
Ward 6	5	33	38	0.6987	30
Ward 9	8	42	50		
Ward 11	5	26	31		
Pay	2	9	11		

There was no significant association between the ward the patient was admitted, whether at ward 6, 9, 11 or pay ward, and the development of shunt infection.

Table 13. Results of the Logit analysis used to determine the effects of selected predisposing factors on the development of shunt infection in pediatric patients at PGH from January 1999 to December 2001.

Factor	Value	Probability
Constant	-0.5104 (-0.355)	0.7222^{ns}
Sex	0.1485 (0.229)	0.8190^{ns}
Concomitant infection	-1.062 (-1.584)	0.1133^{ns}
Surgeon	0.2294 (0.216)	0.8286^{ns}
OR room	-2.1080 (-2.767)	0.0057*
Previous surgery	0.2450 (0.323)	0.7464^{ns}
Prior Diagnostic procedure	-0.2049 (-0.276)	0.7822^{ns}
Shunt revision	-2.0053 (-2.489)	0.0128**
Age	0.0023 (-0.860)	0.3897^{ns}
Nutritional status	0.01766 (0.176)	0.8602^{ns}
Length of admission	0.3643 (2.489)	0.0128**
Duration of OR	0.0578 (0.794)	0.4272^{ns}

ns – not significant at 5% probability level
* - significant at 1% probability level
** - significant at 5% probability level
Figures in parenthesis are T-values

The predisposing factors associated with shunt infection (sex, concomitant infection, surgical composition, OR room, previous diagnostic and neurosurgical procedures, shunt revisions, age, nutritional status, length of hospital admission and duration of OR) were also analyzed in the Logit model in order to determine the significance of each factor to the rate of shunt infection in relation to one another. The T-test was conducted to determine the significance of each explanatory variable in the Logit model. Based on Logit analysis, only the OR room, shunt revision and length of hospital admission were significantly correlated to the rate of shunt infections, with the OR room having the highest significance at 1% probability level.

Antibiotic Prophylaxis

All the patients in this study were given at least 2 prophylactic antibiotics. Prophylactic antibiotics used consisted generally of a combination of intravenous Oxacillin or Cloxacillin and Amikacin or Gentamycin. In 1 case, a combination of Cloxacillin and Ceftriaxone was used. One dose of the antibiotics were given preoperatively then were continued for 1 to 3 days post-operatively.

DISCUSSION

Only a total of 130 charts of pediatric patients who underwent ventriculoperitoneal shunting at UP-PGH from January 1999 to December 2001 were retrieved for review (20 from 1999, 60 from 2000 and 50 from 2001). Our results demonstrated a shunt infection rate of 15.4%/operative procedure. This is within the range of those reported from other centers.[3,7,11,13] In 1984, Odio reported an infection rate of 11% while Walters and Meirovitch reported a shunt infection rate of 21% with a range from 5 to 31%. A similar study, done by Amante et al, from 1993 to 1995 in PGH, showed an infection rate of 11.8%, which is lower than the present shunt infection rate.

Without a definite shunt site infection, the clinical presentation of CSF shunt infection is non-specific, the main symptoms usually reported are fever, irritability and changes in sensorium. Many shunt infections are limited to febrile episodes with bacteria cultured from the CSF in the absence of discernible meningitis. Other reported clinical manifestations of shunt infections aside from indolent fever include abdominal pain, signs of peritonitis, and headache. There may also be erythema over the shunt tract and meningismus. In this study, fever was the predominant clinical presentation (85%), followed by signs of local infection at the shunt site or tract (such as erythema, presence of pus/discharge, abscess formation) in 70%, meningitic symptoms, and symptoms of peritonitis.

In literature, most infections are caused by *S. epidermidis*, followed by *S. aureus*. The reason for *S. epidermidis* to become such a frequent cause of shunt infection, is its property to form a mucoid glycocalyx which protects itself against antimicrobial drugs and host immune responses. The glycocalyx also induces increased adhesion of the bacteria to shunt material. Most infections are a result of intraoperative contamination of the surgical wound by skin flora. Accordingly, coagulase-negative staphylococci are isolated in more than half the cases. *Staphylococcus aureus* is isolated in approximately 20% and gram-negative bacilli in 15%. However this was not observed in this series, were the most common pathogens isolated from the shunt infections were *Staphylococcus aureus, Acinetobacter sp,* and *Klebsiella sp,* with an infection rate of 14.8% each, followed by *Staphylococcus epidermidis* with an infection rate of 11.1%. This however could be explained by the relatively high percentage of shunt infection presenting as localized wound infection (70%) or dehiscence (15%), wherein the expected predominant organism is *Staphylococcus aureus*. There was also a 30% incidence of distal shunt infection in this study, where gram-negative bacteria are expected to predominate and polymicrobial growth is common. Alarming is the apparent resistance of the top microbial isolates to broad-spectrum antibiotics such as the third and fourth generation cephalosporins, and Meropenem; and for the Staphylococci, to Vancomycin. This may be not be accurate and conclusive however since the complete antibiogram of the isolates were not always available.The management of shunt infections in this study consisted of medical treatment with systemic antibiotics and surgery. Surgical interventions done include: 1) shunt removal alone, 2) shunt removal together with an insertion of an external ventricular drainage (through an Ommaya reservoir, a ventriculostomy tube, or exteriorization of the existing shunt), and 3) shunt revision. At present, no single treatment protocol is universally accepted for shunt infections. Reports of success varied regarding treatment with antibiotics alone or in combination with surgery. The majority of authors recommend a course of systemic antibiotics at meningitic dose for 2-3 weeks plus 2 weeks of intraventicular antibiotics, removal of the infected shunt within 48 hours of diagnosis, placement of an external ventricular drainage or serial ventricular taps, and insertion of a new shunt after 10-14 days of negative CSF culture during antibiotic therapy or at least 3 negative CSF culturesafter antibiotics had been discontinued[7,8,10,12]. A decision analysis by Schreffler in 2002 of three treatment strategies showed that the removal of an infected shunt with establishment of an EVD or ventricular taps and administration of antibiotics leads to the highest expected value, 0.86. Removal of an infected shunt followed by immediate replacement and administration of antibiotics is less effective with an expected value of 0.76. The use of antibiotics alone results in the lowest expected value, 0.61.

PREDISPOSING FACTORS TO SHUNT INFECTION:

Age and Sex

Age less than 6 months has been shown to be a risk for developing shunt infection in previous studies. A study by Renier (1984) showed that shunt infection was 2.6 times more frequent before 6 months of age than after 1 year of age. In 1995, a study on shunt infections at PGH by Amante et al observed a higher percentage of children with shunt infection, belonging to the age group less than 6 months (although this was not statistically significant) The explanation for this was a possible relative immaturity of the immune response to bacterial infection in infants, and a higher incidence of shunt revisions in this age group.

Poplc et al. (1992) showed that the higher bacterial density in the skin of the newborn was a risk factor for infection. Furthermore, strains of coagulase negative staphylococci with a higher degree of bacterial adherence are more often found in newborn rather than in older children. Another proposed explanation was the higher temperature and humidity in the operating room during pediatric neurosurgery. In this study, no statistical correlation was observed between ages and rate of shunt infection, and between sexes and shunt infection.

Etiology of Hydrocephalus

There was no statistical association between the etiology of hydrocephalus and shunt infection rate. Amante also noted the same observation in 1995.[12] There were no studies identified relating shunt infections to the etiology of the hydrocephalus. On the other hand, the etiology of hydrocephalus was significantly correlated to shunt revision. Meirovitch reported a predisposition to shunt dysfunction in meningomyelocoele, aqueduct syndrome, infection and perinatal hemorrhage.

Concomitant Infection

The presence of associated foci of infection outside the central nervous system is a risk factor for developing shunt infection due to the possibility of contiguous or hematogenous spread of the infecting organisms. The studies by Renier and Amante both report a significant relationship of concomitant infections to the rate of shunt infections. This however, was not observed in this study.

Neurosurgical Team

In a retrospective study by Borgbjerg of first-time shunted patients, the rate of infection was constant for all variables with the exception of the education of the neurosurgeon, with trainees having a significantly higher rate of infection. This was in contrast to the observations by Amante et al. and Metzemaekers et al. wherein no significant relationship was noted between the experience of the neurosurgeon and the incidence of shunt infection. In this study, there was also no significant association between the composition of the neurosurgical team and shunt infection.

OR room

There was a significantly higher rate of infection when the operation was conducted in the left central block of the operating room complex. This may be due to several factors (such as cleanliness, humidity, ambient temperature, ventilation, medical staff and nurses present, etc.) and requires further investigation.

Previous Surgery and Diagnostic Procedure

Invasive diagnostic procedures (lumbar puncture and vent taps) and neurosurgical operations done prior to shunting is a possible risk factor for developing shunt infection since it favors contamination and entry of infecting organisms. This however was not the case in this study. This can possibly be explained by the administration of at least 2 antibiotics in all cases during the perioperative period, wherein the procedures were performed.

Shunt Revision

Shunt revision was significantly related to the rate of shunt infection in patients with VPS. More revisions done on the shunt favored entry of contaminating organisms thus promoting colonization of the shunt system. Amante similarly reported this finding in his series.[12]

Nutritional Status

Nutritional status was expressed in weight percentiles based on the charts made by the National Center for Health Statistics 2000. In the study by Amante et al. in 1995, the rate of shunt infection was significantly associated to poor nutritional status.[12] This was explained by the ability of a healthy child to withstand the stress of surgical procedures. This was not observed in the present study. A possible explanation is the overall predominance of poor nutritional status of patients in the present study. Only 33 patients (25.4%) belonged to the 50% percentile and above group. A limitation to this analysis is the incomplete anthropometric measurements of patients. The percentile of weight to the height/ length of the patient is a more accurate measurement of nutritional status.

Length of Ward Admission

The length of admission in the wards during the perioperative period had a significant positive correlation to the rate of shunt infection. This may be due to the increased exposure of the subjects to other patients either directly or through their caretakers. This is especially possible in a ward setting were conditions are cramped, facilities are shared, and there are no physical barriers to transmission of infection and other diseases.

Duration of OR

No significant correlation was observed between the duration of OR and the development of shunt infection by Logit analysis.

CONCLUSION

There is a higher rate of infection per operative procedure (15.4%) in PGH from 1999 to 2001 compared to what was previously reported by Amante from 1993 to 1995 (11.8%). This was still within the range of 5 to 31% as reported in foreign centers. Clinical presentation, bacteriologic features paralleled those in foreign literature and etiologic agents than those reported in foreign literature. *S. aureus* and gram negative organisms were more predominant than the *S. epidermidis*. In terms of management, the predominant approach used in this study was the method recommended in foreign studies which include the use of systemic antibiotics in combination with shunt removal, EVD or serial ventricular taps and shunt reinsertion after the shunt infection has resolved.Predisposing risk factors which showed significant correlation to the rate of shunt infection include: the operating room used, a previous shunt revision, and the length of hospital admission at the time of shunting.

LIMITATIONS OF THE STUDY AND RECOMMENDATIONS

The observations made were based only from a small sample size. The author would like to recommend a long-term prospective controlled study with a larger population size in order to come up with more definitive conclusions.

REFERENCES

1. Meirovitch, Joseph; Cohen, Yona-Kitai and Keren, Gershon. Cerebrospinal fluid shunt infections in children. Pediatric Infectious Diseases Journal. 6:921-624, 1987.
2. Borgbjerg, B.M.; Gjerris F.; Albeck M.J. and Borgesen, S.E. Risk of infection after cerebrospinal fluid shunt: an analysis of 884 first-time shunts. Acta Neurochir 136(1-2) :1-7. 1995.
3. Ronan, A., Hogg, G.G., Klug, G. Cerebrospinal fluid shunt infection in children. Pediatric Infectious Diseases Journal. 14:782-786, 1995.
4. Odio, C., McCracken, G.H., and Nelson, J.D. Cerebrospinal fluid shunt in Pediatrics. American Journal of Disease in Children. 138:1103-1108, 1984.
5. Pople, I.K.; Bayston, R. and R.D. Hayward. Infection of cerebrospinal fluid shunts in infants: a study of etiologic factors. Journal of Neurosurgery. 77:29-36, 1992.
6. James, HE; Walsh, J.W.; Wilson, HD; Connor, J.D., et. al. Prospective randomized study of therapy in cerebrospinal fluid shunt infection. Neurosurgery. 7: 459-463, 1980.
7. Gardner P, Leipzig T, Phillips P. Infections of cerebral nervous system: shunts. Medical Clinics of North America. 69:297-314, 1985.
8. Walters, B.C., Hoffmann, H.J., Hendrick, E.B. et al. Cerebrospinal fluid shunt infection: Influences in initial management and subsequent outcome. Journal of Neurosurgery. 60:1014-1021,1984.
9. McGirt M.J., Leveque J.C., Wellons J.C. 3rd, Villavicencio A.T., Hopkins J.S., Fuchs H.E., George T.M. Cerebrospinal fluid shunt survival and etiology of failures: a seven-year institutional experience. Pediatric Neurosurgery 36(5): 248-55. 2000.
10. Tuli S., Drake J., Lawless J., et al. Risk factors for repeated cerebrospinal shunt failures in pediatric patients with hydrocephalus. 92(1): 31-8. 2000.
11. Haines S.J. and Walters B.C. Antibiotic prophylaxis for cerebrospinal fluid shunts: a metanalysis. Neurosurgery. 34(1):87-92.1994.
12. Amante, E.G.; Fojas, M.S.; Lukban, M.B. and A.S. Salonga. Venticuloperitoneal Shunt Infection in Pediatric Patients. UP-PGH Section of Pediatric Neurology. 1995.
13. Metzemaekers, Jan D. Hydrocephaulus shunts: a clinical and laboratory study. Thesis University Groningen. 1998
14. Schreffler R.T.; Schreffler A.J. and R.R. Wittler. Treatment of cerebrospinal fluid shunt infections: a decision analysis. Pediatric Infectious Disease Journal. 21:632-636, 2002.
15. Nelson, Waldo E. Textbook of Pediatrics, 16th ed. 17:789 790, 2000.