Egyptian Journal of Neurosurgery

RESEARCH

Open Access

Randomized trial of shunt infection rates comparing intraoperative Vancomycin versus Gentamicin in ventriculoperitoneal shunt system preparation

Surajudeen A. Olomo[1], Joseph O. Obande[1*], Gyang M. Bot[2] and Peter O. Binitie[2]

Abstract

Background Ventriculoperitoneal (VP) shunt is the mainstay of surgical management of patients with hydrocephalus. The insertion of ventriculoperitoneal shunt may be accompanied by many potentially life-threatening complications including shunt infection. Concerted efforts have been made to reduce shunt infection rates, including use of saline- antibiotic solutions containing antibiotics such as Gentamicin, mixture of Gentamicin and Vancomycin in shunt system preparation. We therefore set out to determine the infection rates following the use of intraoperative Gentamicin and Vancomycin in ventriculoperitoneal shunt system preparation and compare the infection rates. Therefore, a randomized single blind comparative study was carried out for a period of seventeen months, among 56 patients that presented to 2 tertiary health centers in Nigeria diagnosed of hydrocephalus. Patients were randomized into Vancomycin- and Gentamicin-shunt preparation groups. The outcome measure was postoperative shunt infection rates. Statistical analysis was performed using SPSS software (version) 21. Group comparisons were made using the Student's t-test for numerical variables, and chi-square test or fisher's exact test for categorical variables. Statistical significance was inferred at p-value < 0.05.

Result Fifty-six patients were included in the study. One patient was lost to follow-up in Vancomycin group. Another patient died in Gentamicin group of sudden death without the patient exhibiting symptoms of shunt infection leaving a total of 54 for analysis. All the patients included in the study were followed up for six months. Their mean ages were between 1688.5 ± 665.3 (days) for Vancomycin group and 10,222 ± 6635.8 (days) for Gentamicin group. There was male preponderance of 55.6% as against female of 44.4%. Majority of the hydrocephalus were of congenital cause accounting for 64.8%. There was one shunt infection in the Gentamicin group giving rise to an infection rate of 1.9% which was not statistically significant (*P* –value—0.313). The organism isolated was *Pseudomonas* species.

Conclusion Ventriculoperitoneal shunt infection rates can be reduced to the barest minimum if standard concentration of antibiotics is used to prepare the shunt hardware employing a standard surgical technique.

Keywords Ventriculoperitoneal shunt, Shunt infection, Vancomycin, Gentamicin

*Correspondence:
Joseph O. Obande
obandejo@yahoo.com
[1] Division of Neurosurgery, Department of Surgery, University of Abuja Teaching Hospital, Gwagwalada, Abuja, Nigeria
[2] Department of Surgery, Neurosurgery Unit, Jos University Teaching Hospital, Jos, Plateau State, Nigeria

Background

The placement of ventriculoperitoneal shunt remains the mainstay in the surgical management of hydrocephalus [1].Ventriculoperitoneal shunting is a popular method of cerebrospinal fluid diversion [1]. It is a suitable technique for most patients with hydrocephalus from any aetiology

such as myelomeningocele, aqueductal stenosis, post infective hydrocephalus, brain tumor with obstructive hydrocephalus and other acquired conditions [1]. As a result of increased use of shunt for treatment of hydrocephalus, the incidence of shunt complications especially shunt infection has been on the rise [2, 3]. Infections are common complication of ventriculoperitoneal shunt placement; the shunt infection rate ranges from 8 to 15%. [4, 5] An infection usually leads to shunt removal with subsequent re-insertion of new shunt, this leads to prolonged hospital stay [6]. It is widely accepted that most shunt infections occur intraoperatively from different sources [7]. Shunt infections are largely due to skin flora colonization of shunt device at surgery [6], wound breakdown over the shunt components, heamatogenous spread from another source and retrograde extension from perforated viscus or peritoneal infection [1]. Most of the infections are caused by staphylococcus species especially *staphylococcus epidermidis*. [8] Over 50% of staphylococcus infections occur within the first 2 weeks post-shunt implantation, and 70% within 2 months. [8] It is estimated that in about 3% of shunt operations the cerebrospinal fluid is already infected [8]. Therefore most shunt infections occur within the first 3 months of shunt insertion [2]. Shunt infection is reported to occur more frequently in some groups of patients especially neonates and children less than 1 year, [9, 10] open neural tube defects, length of procedure, the cause of the hydrocephalus [11],repeat shunt revisions [11], emergency abdominal surgery [12], percutaneous placement of feeding gastrostomy tube [13], presence of gastrostomy tube during the shunt procedure [14] and in the setting of temporary external ventricular drain [15, 16]. Shunt infection has significant impact on patients; in terms of health related quality of life, cognitive function and intelligent quotient, survival of patients, with the number of shunt infections becoming an independent predictor of death [16]. Impacts on health services are also significant; these include the requirement for prolonged hospital admission, additional surgery to remove infected hardware, placement of temporary external ventricular device, and further surgery to place a new shunt once the infection has been treated [16]. Development of loculations within cerebrospinal fluid compartments and even death are further sequalae of shunt infections [17]. Measures have been taken to reduce shunt infection rates: Preoperative intravenous antibiotics are administered routinely and this is the mainstay of prevention [6]. Many other different measures have contributed in reducing shunt infection rates. One of these measures is the use of antibiotics impregnated catheter, leading to prolonged pericatheter release of antibiotics [6, 16]. Use of antibiotics impregnated shunts are constrained in resource-poor setting by high cost, non-availability, and associated growing concern of development of antibiotics resistance [6]. Quality improvement research has suggested that standardized protocols may reduce device-related infection in a number of areas [18]. The Hydrocephalus Clinical Research Network (HCRN) has used this approach to minimize shunt infection rates since 2007 [18]. It therefore developed a protocol using available literature that included 11 steps aimed at reducing shunt infection, such as hand washing, double gloving, use of perioperative antibiotics and patient positioning [18]. Others are no touch techniques, reduction in the number of staff in the operating room, change of gloves when handling the shunt hardware. An assessment of this protocol in 2011 demonstrated a reduction in infection rates [18]. Most protocols employ gentamicin to prepare shunt system during surgery, and the infection rate is less than desired. A previous study by Uche EO et al. on the determinants and outcomes of ventriculoperitoneal shunt insertion in Enugu, Nigeria, reported an infection rate of 8.6% [19], while another study on cerebrospinal fluid shunting complication by Komolafe EO, Adeolu AA, and coworkers, reported an infection rate of 19.4% from a new Neurosurgical center in South West Nigeria [20]. Studies have shown that addition of Vancomycin to the existing protocol for shunt preparation reduced shunt infection rate from 6.8 to 3% [6]. Gentamicin, an antibiotic is an aminoglycoside that has a good coverage for Gram-negative organisms. Most shunt infections are caused by *Staphylococcus epidermidis*, which is susceptible to gentamicin [19–21], followed by *Staphylococcus*. Vancomycin is a very potent bactericidal glycoprotein antibiotic with a proven activity against Staph species. Vancomycin has been used to treat Methicillin resistant *Staphylococcus aureus*. [22] Some studies have noted the efficacy of Vancomycin on biofilms of infected shunt hardware [23]. Therefrom, we set out to investigate the effect of Vancomycin on shunt hardware preparation and compare its infection rates with Gentamicin shunt hardware preparation.

Methodology

It was a prospective randomized single blind comparative study, carried out over a period of seventeen months between the months of May 2020 to September 2021, in North Central Nigeria at 2 tertiary health institutions, being, Jos University Teaching Hospital, Jos, a 600-bedded hospital and University of Abuja Teaching Hospital, Gwagwalada, a 550-bedded hospital. All consecutive patients with hydrocephalus who presented to the neurosurgery divisions at the Jos University Teaching Hospital and University of Abuja Teaching Hospital Gwagwalada were recruited. All patients with hydrocephalus whose

parents and or caregivers gave consent and who met indications for ventriculoperitoneal shunt insertion were included in the study. Exclusion criteria included previous shunt infection, multiloculated hydrocephalus requiring multiple ventriculoperitoneal shunt or neuroendoscopy and immunosuppressed patients.

Patients' demographics and other variables were obtained and entered in the study proforma. Patient who met the inclusion criteria were enrolled into the study using a computer-generated randomization method on the day of the surgery. Patients with history of hypersensitivity to Vancomycin were excluded before randomization. Vancomycin and Gentamicin were stored at the pharmacy at a temperature recommended by the manufacturer (20 °C–25°C). Vancomycin-saline and Gentamicin-saline were prepared intraoperatively using 500 mg of Vancomycin in 250mls of normal saline to create 2 mg of Vancomycin per 1 ml of saline [6] and 400 mg of Gentamicin in 200mls of normal saline to create 2 mg of Gentamicin per 1 ml of normal saline [21].The shunt catheter was subsequently immersed in the saline-antibiotics solutions. Ventriculoperitoneal shunt insertion was performed using standardized protocol (Fig. 1) utilizing the Chabra$^{(R)}$ slit-and-spring-mechanism medium-pressure type of shunt. Postoperatively, all the patients were standardized to be seen at the first two weeks, one month, two months and three months after discharge from the hospital. During these periods of follow-up, all the patients were examined for the criteria used for the diagnosis of shunt infection in this study. Parents or guardians of the patients were counseled to present to the hospital at any time once they noticed fever, vomiting, inconsolable cry and irritability in the patient. Additionally, for the purpose of this study, the diagnosis of shunt infection was made based on the following criteria: axillary temperature greater than 38°C not attributable to any other cause either during admission or during the follow-up periods, Skin hyperemia or tenderness along the shunt tract, and features of meningeal irritation such as neck stiffness, positive Kerning's or Brudzinski's sign in a patient with a shunt. Following clinical suspicion of a shunt infection, confirmation was made by CSF aspiration from the shunt chamber in an aseptic manner and subsequent performance of microbiological studies.

Statistical analysis

Statistical analysis was done using the Statistical Package for Social Sciences (SPSS) version 21, Chicago, Illinois USA. Results obtained were expressed using tables, charts, and mean ± standard deviation. Simple frequencies were used to determine patients' demographics. Comparison of shunt infection rate with the use of Vancomycin versus Gentamicin in shunt system preparation was determined using fisher's exact test. Statistical significance was inferred at *p-value* of < 0.05.

Results

Demographic parameters

Table 1 A total of 17 patients were males accounting for 63.0% and 10 patients were female (37.0%) in Vancomycin group, and 13 patients were male (48.1%) and 14 were females (51.9%) in Gentamicin group with chi square value of 1.200 and P-0273.

Their mean ages were 1688.5 ± 665.3 (days) for Vancomycin group and 10,222 ± 6635.8 (days) for Gentamicin group with t-test 1.280 and *P*-value 0.212, respectively.

Presenting symptoms

Table 2 Outlines patients' presenting symptoms. Head enlargement was the most common presenting symptoms with a mean of 268.8 ± 139.1 for Vancomycin group and 75.3 ± 16.9 for Gentamicin group. The t-test value was 1.382. The difference in presenting symptoms between the two groups was not significant (P-value 0.184).

Examination findings

Table 3 The most common examination finding was head enlargement with head circumference mean of 50.0 ± 8.3 in Vancomycin group and 44.9 ± 5.7 in Gentamicin group. The *t*- test was 2.282 in Table 3A with a *P*-value 2.282, which was not significant.

Aetiologies of hydrocephalus

Table 4 shows the etiology of hydrocephalus. The most common cause of hydrocephalus from this study was congenital which accounted for 17(63.0%) in Vancomycin group and 18(66.7%) in Gentamicin group, while trauma and vascular were the least etiology identified in both groups1 (3.7%). The difference in etiology between the two groups was not significant (*P*-0.770).

This result is expressed graphically in Fig. 2.

Outcome

Table 5 shows the outcome from the study. One patient (3.7%) had shunt infection in Gentamicin group and none (0.0%) in Vancomycin group. The difference in infection rates was not significant (p-value 0.313). The risk ratio in the infected group was 2.0. All patients enrolled in this study were followed up for six months.

Discussion

Main findings from this study

Shunt infection is a severe complication of ventriculoperitoneal shunt insertion. It is an undesired complication of ventriculoperitoneal shunt surgery with increased

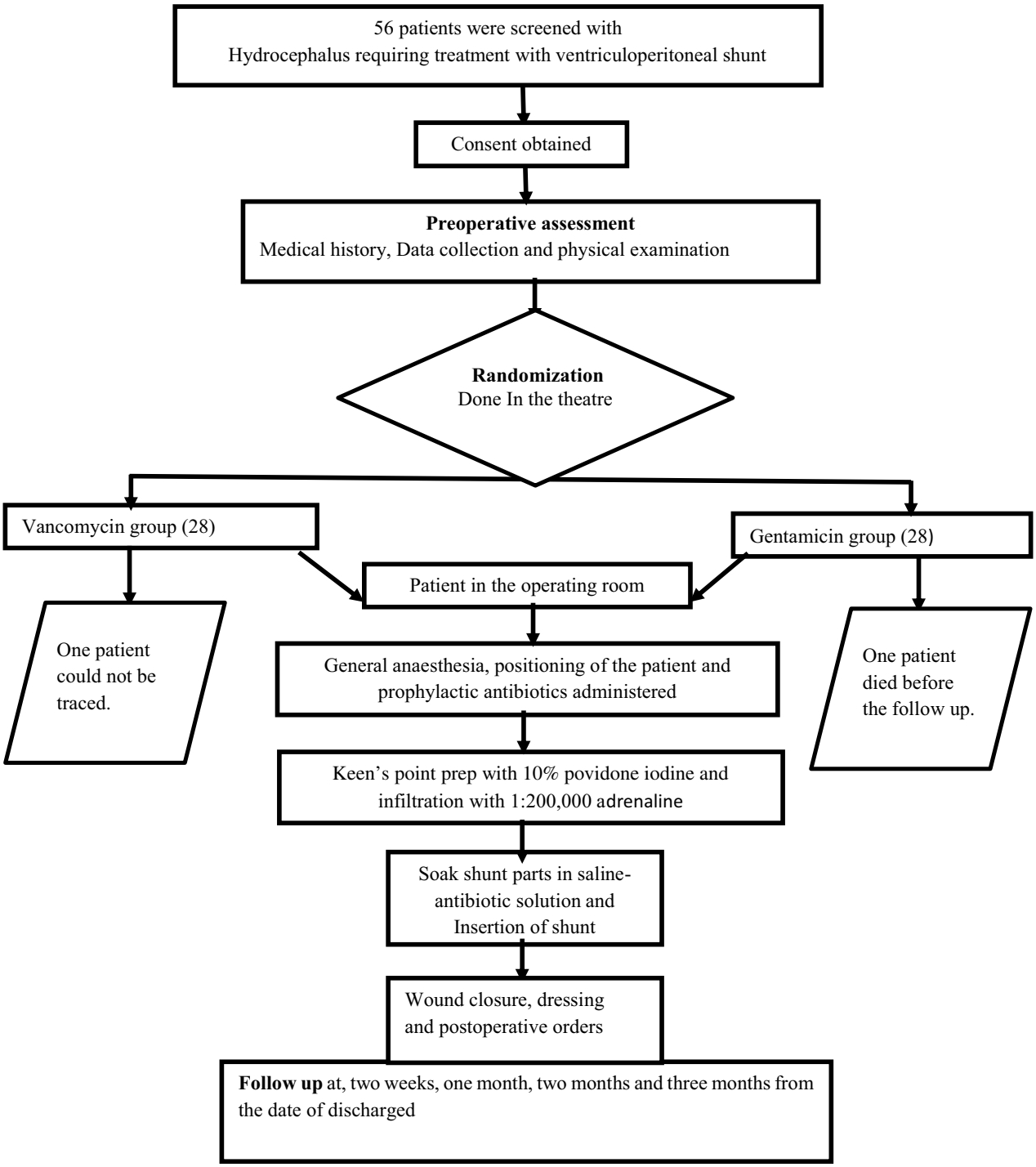

Fig. 1 Selection criteria, randomization, and intraoperative shunt catheter preparation with vancomycin and gentamicn saline irrigation

morbidity and economic burden on health. The study being to determine the infection rates following the use of intraoperative Vancomycin and Gentamicin to prepare ventriculoperitoneal shunt and compare their infection rates. A total of 56 patients were enrolled in this study. One patient was lost to follow up. Another died during the follow-up period, at the second month of follow-up. The death was attributable to sudden-infant death syndrome as the child was found dead in the morning without an obvious clinical event previously. The possible

Table 1 Sociodemographic Characteristics of Patients Showing Their Sex and Age Distribution

Variables	Group				
	Vancomycin *n* = 27 n (%)	**Gentamicin *n* = 27 n (%)**	**Total *N* = 54 n (%)**	**OR(CI)**	***P*-value**
Sex				1.200(0.618–5.425)	0.273
Male	17(63.0)	13(48.1)	30(55.6)		
Female	10(37.0)	14(51.9)	24(44.4)		
Variables	**Mean ± SD**	**Mean ± SD**	***t***	**CI**	***P*-value**
Age (days)	1688.5 ± 665.3	10,222 ± 6635.8	1.280	− 22,229.7 − 5160.9	0.212

Table 2 PRESENTING SYMPTOMS

Variables	Group				
	Vancomycin Mean ± SD	**Gentamicin Mean ± SD**	***t***	**CI**	***P*-value**
Altered consciousness	14.9 ± 0.6	14.2 ± 2.3	1.372	− 0.3–1.6	0.181
Head enlargement(days)	268.8 ± 139.1	75.3 ± 16.9	1.381	− 100.2–487.2	0.184
Variables	**Vancomycin *n* = 27 n(%)**	**Gentamicin *n* = 27 n (%)**	**Total *n* = 54 n (%)**	**OR(CI)**	***P*-value**
Fever				2.2(0.4–13.0)	0.669[f]
Yes	4(14.8)	2(7.4)	6 (11.1)		
No	23(85.2)	25(92.6)	48 (88.9)		
Seizures				3.6(0.7–19.6)	0.250[f]
Yes	6(22.2)	2(7.4)	8 (14.8)		
No	21(77.8)	25(92.6)	46 (85.2)		
Vomiting				1.2(0.4–4.3)	0.750
Yes	7(25.9)	6(22.2)	13 (24.1)		
No	20(74.1)	21(77.8)	41 (75.9)		
Poor appetite				1.0(0.1–7.7)	1.000
Yes	2(7.4)	2(7.4)	4 (7.4)		
No	25(92.6)	25(92.6)	50 (92.6)		
Incessant cry				–	0.491[f]
Yes	2 (7.4)	0(0.0)	2 (3.7)		
No	25(92.6)	27(100.0)	52 (96.3)		
Head trauma				1.0(0.1–16.9)	1.000
Yes	1(3.7)	1(3.7)	2 (3.7)		
No	26 (96.3)	26(96.3)	52 (96.3)		

[f] -fisher's exact test

cause of the patient's death could not be attributed to shunt failure from shunt infection as the patient had no symptoms suggestive of shunt infection when the parents were interrogated. There was male preponderance accounting for 30% (55.6) and female 24% (44.4), but not statistically significant (p-value 0.237), (Table 1). Gender has not been found to have any association with hydrocephalus [24, 25]. An infection occurred in Gentamicin group giving rise to an infection rate of 3.7%. No infection was recorded in Vancomycin group (0.0%). The overall infection rate was 1.9% and showed no statistically significant between the 2 forms of shunt hardware preparation (p-value of 0.313).

Symptoms of shunt infection in the affected patient started on the 19th day post-surgery, following which the patient was admitted on the same day, clinical findings

Table 3 Examination findings

Variables	Group				
	Vancomycin Mean ± SD	**Gentamicin Mean ± SD**	***t***	**CI**	***P*-value**
Pupil equally reacting to light(mm)	3.0 ± 0.0	3.2 ± 0.7	1.412	−0.5–0.1	0.170
Head circumference(cm)	50.0 ± 8.3	44.9 ± 5.7	2.282	0.6–9.6	0.028*
Variables	**Vancomycin *n* = 27 n (%)**	**Gentamicin *n* = 27 n (%)**	**Total *n* = 54 n (%)**	**OR(CI)**	**P-value**
Setting sun sign				2.4 (0.6–9.3)	0.327[f]
Yes	8 (29.6)	4 (14.8)	12 (22.2)		
No	19 (70.4)	23 (85.2)	42 (77.8)		
Distended veins				1.9 (0.6–6.2)	0.248
Yes	11 (40.7)	7 (25.9)	18 (33.3)		
No	16 (59.3)	20 (74.1)	36 (66.7)		

[f] -fisher's exact test*Significant at 95%[t]t-test statistic

Table 4 Etiologies of Hydrocephalus

Variables	Group				
	Vancomycin *n* = 27 n (%)	**Gentamicin *n* = 27 n (%)**	**Total *N* = 54 n (%)**	**χ^2**	***P*-value**
Aetiology				1.814	0.770
Congenital Hydrocephalus	1 7(63.0)	18 (66.7)	35 (64.8)		
Neoplastic	3 (11.1)	5 (18.5)	8 (14.8)		
Vascular	1 (3.7)	1(3.7)	2 (3.7)		
Trauma	1 (3.7)	1 (3.7)	2 (3.7)		
Infective	5 (18.5)	2 (7.4)	7 (13.0)		

revealed a temperature of 39.6°C, shunt tract tenderness and neck stiffness, cerebrospinal fluid sample taken, and microbiological shunt infection confirmed on the 22nd day post-shunt insertion. Empirical 3rd generation cephalosporin-Ceftriaxone was commenced as standard protocol while awaiting the outcome of the cerebrospinal fluid analysis result. The organism isolated was *Pseudomonas* spp. The antibiotic was changed to Ceftazidime and ciprofloxacin based on the sensitivity results. Negatives cerebrospinal fluid results were obtained on day 13th and 15th post admission. New shunt re-insertion was performed on day 17th using the left side, being opposite to the previous site of infection. Patient was discharged after spending 22 days on admission. The patient that developed shunt infection had both ventriculoperitoneal shunt insertion and lumbosacral myelomeningocele repaired at the same sitting. There were 4 patients in Gentamicin group and two in Vancomycin group who had both ventriculoperitoneal shunt insertion and repair of myelomeningocele done at the same sitting. Only one in Gentamicin group developed shunt infection and none in Vancomycin group. The back wound of the patient that developed shunt infection healed perfectly, making the repaired myelomeningocele an unlikely source of the infection. Furthermore, at the time of surgery, the myelomeningocele sac was intact and there were no signs of infection in the patient. Nevertheless, there might be inoculation at the time of surgery and this may account for the organism isolated.

Comparison of these findings with previous studies

Timing of shunt infection

The interval between ventriculoperitoneal shunt insertion and the development of shunt infection from this study occurred by 19th day of shunt insertion. The timing of this infection was within the period when shunt infection is common, in keeping with the study by Wu X that most shunt infections occur within 30 days of ventriculoperitoneal shunt insertion [26]. Equally, it is in conformity with the findings by Bassani *et al* [2] and Greenberg [8] that most shunt infections occurred within the first three months of shunt insertion. McGirt et *al* [9] and Vinchon *et al* [10] had noted that shunt infection is common in neonates and patients within one year of age, our patient is the same age bracket.

Organism isolated

Most ventriculoperitoneal shunt infections are caused by a coagulase negative Gram-positive *Staphylococcus epidermidis* which is a skin commensal and infects shunt at insertion. *Staphylococcus epidermidis* accounts for 47% to 64% of all Gram-positive shunt infection [27, 28]. In this study, the organism isolated from the infected

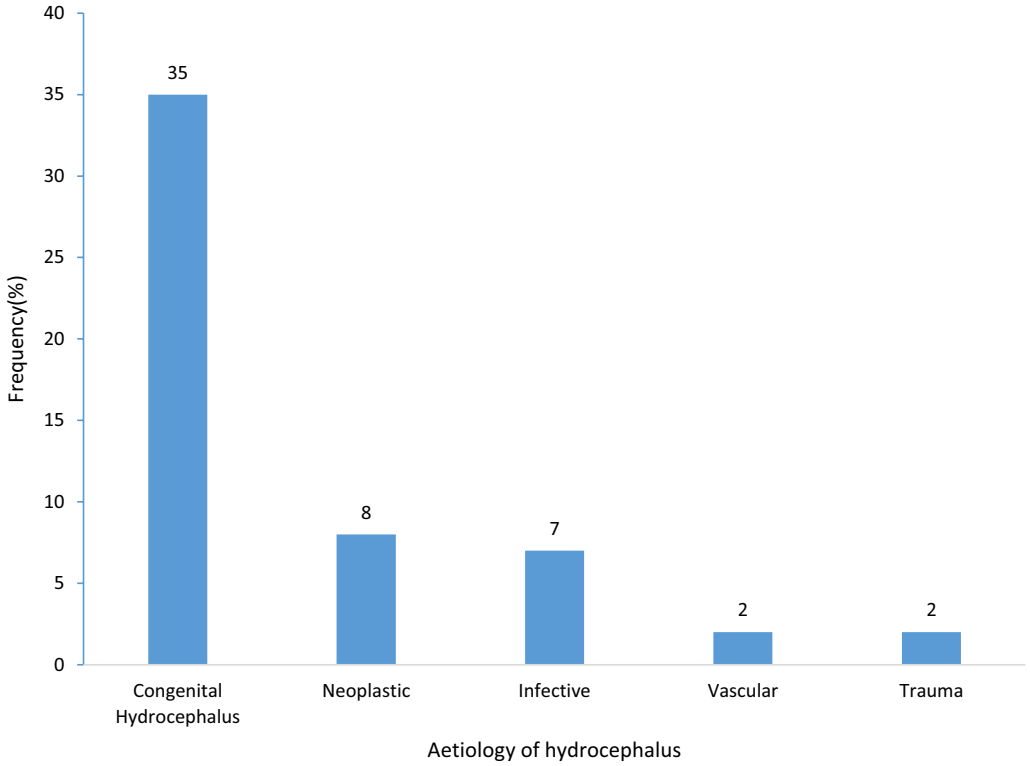

Fig. 2 Bar chart of Etiologies of Hydrocephalus

Table 5 Outcome

Variables	Group				
	Vancomycin *n* = 27 n (%)	**Gentamicin *n* = 27 n (%)**	**Total *n* = 54 n (%)**	**RR(CI)**	***P*-value**
Shunt infection				2.0(1.5–2.7)	0.313[f]
Yes	0(0.0)	1(3.7)	1(1.9)		
No	27(100.0)	26(96.3)	53(98.1)		

[f] -fisher's exact test

cerebrospinal fluid was *Pseudomonas* spp. This is not common. This finding was in contrast to publication by Moussa et al., [27] *Prusseitet al,* [28] and Greenberg [8]. Most publications reported *Staphylococcus epidermidis*. The reasons for the isolation of pseudomonas from the cerebrospinal fluid may be attributed to the fact that the organism can colonize the gastrointestinal system, migrating along the peritoneal catheter to cause ascending shunt infection. Uche et al., [19] recorded similar findings in his study. Of note, publications by Prusseit*et al*, [28] Van Linder*et al*, [6] and Wu et al., [26] cultured *Pseudomonas* spp from cerebrospinal fluid aspirate following ventriculoperitoneal shunt insertion in children unlike in the British study. [29]

Length of hospital stay

Length of hospital stay was 22 days. This is in keeping with the study by Kestle et al. [21]

Infection rates

The infection rate in the Gentamicin group is 3.7% with the overall infection rates of 1.9% (P-0.313) which was not statistically significant. Contrastingly, this was lower compared to study by Komolafe et al. who recorded 19.4% [20]. Uche et al.,6.6% [19], Simon 11% [4, 5], Gathura et al. [24] findings from this study are similar to infection rates of 3% reported by Van Lindert et al. [6] indicating that in properly controlled environments the infection rates can be very minimal.

Conclusion

Ventriculoperitoneal shunt infection rates can be reduced to the barest minimum if standard concentration of antibiotics was used to prepare the shunt hardware and strict asepsis was observed as overall ventriculoperitoneal shunt infection rate was 1.9%. Given that the infection rate in Gentamicin group was 1 (3.7) % and the overall infection rate from the study was 1 (1.9) % with a p-value of 0.313, there is no statistically significant difference between Vancomycin prepared shunt hardware and Gentamicin prepared shunt hardware.

Acknowledgements
Not applicable

Author contributions
SAO conceptualized, recruited and participated in the patients' surgeries and was involved in the analysis and interpretation of the patient data. JOO participated in the surgeries, and was a major contributor in writing the manuscript. GMB participated in the surgeries, and was a major contributor in writing the manuscript. POB contributed in writing the manuscript. All authors read and approved the final manuscript.

Funding
The authors declare that no funding was received for this research and no funding body was involved nor contributed to the design of the study and collection, analysis, and interpretation of data and in writing the manuscript.

Availability of data and materials
The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
Ethical clearance was obtained from Research and Ethical committee of Jos University Teaching Hospital and University of Abuja Teaching Hospital Gwagwalada.

Consent for publication
Consent was obtained from participants at point of recruitment for the information obtained from the study to be used for publication.

Competing interests
The authors declare that they have no competing interests.

Received: 28 September 2023 Accepted: 7 October 2023
Published online: 16 November 2023

References

1. Rani RV. A study on ventriculoperitoneal shunts infections. (Dissertation). Chennai. Madras Medical College; 2006.
2. Bassani L, Riva-Cambrin J. Management and prevention of shunt infection. In: Richard Winn. H. Youmans and Winn Neurological Surgery, 7th edition. Philadelphia, ELSEVIER; 2017. pp 6226–6237.
3. Kulkarni AV, Rinva-Cambrin J, Butler J, et al. Outcomes of CSF shunting in children: comparison of Hydrocephalus Clinical Research Network cohort with historical controls: clinical article. J Neurosurg Pediatr. 2013;12:334–8.
4. Simon TD, Riva-Cambrin J, Srivastava R, et al. Hospital care for children with hydrocephalus in the United States: utilization, charges, comorbidity, and deaths. J Neurosurg Pediatr. 2008;1:131–7.
5. Simon TD, Hall M, Riva-Cambrin J, et al. Infection rates following initial cerebrospinal fluid shunt placement across pediatric hospitals in the United States. J Neurosurg Pediatr. 2009;4:156–65.
6. Van Lindert EJ, et al. Topical Vancomycin reduces cerebrospinal fluid infection rate: a retrospective cohort study. PLoS ONE. 2018;13(1): e0190249. https://doi.org/10.1371/journal.pone.0190249.
7. Atiq-UR R, Tausir-ER R, Hassan HB, Vikas G. A simple method to reduce infection of ventriculoperitoneal shunt. J Neurosurg Pediatrics. 2010;5:569–72.
8. Mark S. Greenberg Shunt infection, Handbook of Neurosurgery. 8th ed. New York: Thieme; 2016. p. 339–42.
9. McGirt MJ, Zaas A, Fuchs HE, et al. Risk factors for pediatric ventriculoperitoneal shunt infection and predictors of infectious pathogens. Clin Infect Dis. 2003;36:858–62.
10. Vinchon M, Dhellemmes P. Cerebrospinal fluid shunt infection: risk factors and long-term follow-up. Childs Nerv Syst. 2006;22:692–7.
11. Simon TD, Whitlock KB, Riva-Cambrin J, et al. Revision surgeries are associated with a significant increased risk of subsequent cerebrospinal fluid shunt infection. Pediatr Infect Dis J. 2012;31:551–6.
12. Mortellaro VE, Chen MK, Pincus D, et al. Infectious risk to ventriculoperitoneal shunts from gastrointestinal surgery in the pediatric population. J Pediatr Surg. 2009;44:1201–4.
13. Roeder BE, Said A, Reichelderfer M, et al. Placement of gastrostomy tubes in patients with ventriculoperitoneal shunts does not result in an increased incidence of shunt infection or decreased survival. Dig Dis Sci. 2007;52:518–22.
14. Simon TD, Butler J, Whitelock KB, et al. Risk factors for the first cerebrospinal fluid shunt infection: findings from a multi-center prospective cohort study. J Pediatr. 2014;164:1462–8.
15. Simon TD, Hall M, et al. Infection rate following initial cerebrospinal fluid placement across pediatric hospitals in the United States. J Neurosurg Pediatrics. 2009;4:156–65.
16. Jenkisen MD, Gamble C, et al. The British antibiotics and silver-impregnated catheters for Ventriculoperitoneal shunt multi-centre randomized control trial (the BASICS Trials): study protocol. Trials. 2014;4:15.
17. Klimo PJR, Thompson CJ, Baird CL, Flannery AM. Paediatric Hydrocephalus: systemic literature review and evidence-based guidelines Part 7: Antibiotic-impregnated shunt versus conventional shunt in children: a systemic review and meta-analysis. J Neurosurg Pediatrics (Suppl). 2014;14:53–9.
18. Kestle JRW, Holublov R, Cochrane D, et al. A new hydrocephalus clinical research network protocol to reduce cerebrospinal fluid infection. J Neurosurg Pediatrics. 2015;8:22–9.
19. Uche EO, Onyia E, Mezue UC, et al. Determinants and outcome of ventriculoperitoneal shunt infections in Enugu. Nigeria Paediatr Neurosurg. 2013;49:75–80.
20. Komolafe EO, Adeolu AA, Komolafe AM. Treatment of cerebrospinal fluid shunting complication in Nigeria program. Paediatr Neurosurg. 2008;44:36–42.
21. Kestle JRW, Riva-Cambrin J, Wellons JC, et al. A Standardized protocol to reduce cerebrospinal fluid shunt infection the hydrocephalus clinical research network quality improvement initiative. J Neurosurg Pediatrics. 2011;8:22–9.
22. Ragel BT, Browd SR, Schmidt RH. Surgical shunt infection: significant reduction when using intraventricular and systemic antibiotic agents. J Neurosurg. 2006;105:242–7.
23. Bayston R, Ullas G, Ashraf W. Action of linezolid or vancomycin on Biofilms in ventriculoperitoneal shunts In Vitro. J ASM org. 2012;56:2842–5.
24. Mulugeta B, Seyoum G, Mekonnen A, et al. Assessment of the prevalence and associated risk factors of pediatric hydrocephalus in diagnostic centers in Addis Ababa. Ethiopia BMC Pediatr. 2022;22:145. https://doi.org/10.1186/s12887-022-03212-6.
25. Gathura E, Poenaru D, Bransford R, Albright AL. Outcome of ventriculoperitoneal shunt infection in Sub-Saharan Africa. J Neurosur: Pediatrics. 2010;6:329–35.
26. Wu X, Liu Q, Jiang X, Tzang T. Prevention options for ventriculoperitoneal shunt infection: a retrospective analysis during a five-year period. Int J Clin Exper Med. 2015;8(10):19775–80.
27. Moussa WMM, Mohamed MAA. Efficacy of postoperative injection of antibiotics in and around ventriculoperitoneal shunt in the reduction

of shunt infection: a Randomized control trial. Clin Neurol Neurosurg. 2016;143:144–9.
28. Prusseit J, Simon M, et al. Epidemiology prevention and management of Ventriculoperitoneal Shunt Infection in Children. Pediatric Neurosurg. 2009;45:325–36.
29. Steven NT, Greene CM. Ventriculoperitoneal shunt-related infection caused by Staphylococcus Epidermidis: pathogenesis and implications for treatment. Br J Neurosurg. 2012;26(6):792–7.

Publisher's Note