



# Towards zero infection for ventriculoperitoneal shunt insertion in resource-limited settings: a multicenter prospective cohort study

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## Abstract

**Introduction** Shunting for hydrocephalus can lead to improvement in the quality of life although the latter has been subdued by complications like shunt infection. Established protocols have contributed to the reduction of ventriculoperitoneal shunt (VPS) infections. Previously, we retrospectively demonstrated a low infection rate despite some of the protocol recommendations not being implemented. The aim of this study was to prospectively establish the incidence of shunt infection in the early post-shunt period following our protocol and elucidate on associated risk factors.

**Patients and methods** A multicenter prospective descriptive cohort study of consecutive 209 under-5 children requiring VPS for hydrocephalus was conducted between January 2013 and November 2018. An innovative protocol insisting on intermittent application of povidone-iodine on the skin during the operation was implemented. The patients were followed-up for 3 months post-surgery.

**Results** Included were 211 VPS procedures performed on 209 children. The median age was 9 months and 84 were males. Hydrocephalus was non-communicative in 72.0% and aqueductal stenosis was its most frequent cause (84.9%). Most surgeries were performed in the morning (90.5%), electively (95.3%), and for the first time (91%). The median duration of surgery was 65 min. Shunt infection rate was 1.9% ( $n = 4$ ) (95% CI 0.7 to 5.0%) per procedure.

**Conclusion** The observed infection rate was low. This suggests that the protocol followed captured the most critical components necessary to ensure low infection rates and that simple measures implemented in economically challenged environments may achieve internationally acceptable infection rates.

**Keywords** Complication · Hydrocephalus · Infection · Pediatric · Surgery · Ventriculoperitoneal shunt

## Abbreviations

CSF	Cerebrospinal fluid
VPS	Ventriculoperitoneal shunt
ETV	Endoscopic third ventriculostomy
EVD	External ventricular drainage
HCP	Hydrocephalus

## Introduction

Hydrocephalus is the most frequent neurosurgical problem encountered in children in our setting [10] and worldwide [17]. Ventriculoperitoneal shunt (VPS) is a common neurosurgical procedure in the therapeutic armamentarium for hydrocephalus [15]. Although the resurgence of endoscopic third ventriculostomy (ETV) with its advantages is an appealing alternative [3], conventional CSF shunting is still a treatment option with excellent prognosis in many hydrocephalic patients [17]. However, the gains in the quality of life after shunting are often subdued by significant failure rates from complications like malfunction and shunt infection [29] and dissatisfaction from their long-term morbidity. Mortality rates are still elevated ranging from 10 to 15% [18] to as high as 30–40% [8, 19]. The risk of subsequent morbidity leads to increase in resources spent to treat a potentially preventable illness against a background of limited resources in Africa.

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Several established protocols have repeatedly contributed to reduction of VPS infections [2, 12, 13, 20, 25–27] yet “zero infection” is still a far cry. With reported risk of early infection after shunt surgery ranging from 3 to 20% [2, 7, 14, 23, 33], current acceptable infection rates are less than 5–7% [18]. Fifty percent of shunt infections occur within 2 weeks post-shunt [18], 70% [2] to 90% [9] within 30 days, and more than 90% within 6 months [1, 2, 21] post-surgery; most being staphylococcal infections from the skin [8, 18]. Therefore, shunt infection in most cases is a complication of shunt surgery [2] and could/should be mitigated and averted.

Previously, we [22] reported low infection rates of 3.5% per procedure by rigidly adhering to some of the recommendations of infection minimizing protocols [2, 26]. Because not the entirety of the recommendations was implemented, our results suggested that some of the measures in the protocols have minimal or no effect on infection reduction hence the need for adapted protocols tailored to our setting to avoid future irrational use of scarce resources. The fact that the exact causes or the relative contribution of identified risk factors remains unascertained necessitates the identification of factors associated with shunt infection locally.

The purpose of this study was thus to prospectively establish the incidence of shunt infection in the early post-shunt period at three separate countries where our protocol was implemented, and elucidate on associated risk factors.

## Patients and methods

### Study design, setting, and period

This was a non-concurrent, multicenter, prospective descriptive cohort study [6] of consecutive 209 under-5 children requiring VPS for hydrocephalus. The children were recruited from three countries (Zimbabwe, Namibia, and Democratic Republic of Congo) and prospectively observed and followed-up from admission for surgery to 3 months post-surgery during the period of January 1, 2013, to November 30, 2018. The initial cohort study was conducted at two university teaching hospitals in Harare (the only institutions with pediatric neurosurgery service in Zimbabwe) and the protocol replicated in Oshakati (Namibia) and Lubumbashi (DRC) hospitals.

### Study population

#### Sampling and recruitment

Consecutive patients were entered into the study on the day of shunt insertion. Informed consent forms were signed by the consenting parent or guardian of study subjects.

- Inclusion criteria:
  - Patients with hydrocephalus requiring VP shunt surgery
  - Patients aged 5 years or less on the day of shunting
- Exclusion criteria:
  - Patients with hydrocephalus treated by alternative diversion instead of VPS
  - Patients with pre-existing CSF infection on culture of intra-operatively collected CSF sample

### Sample size justification

We planned a prospective cohort study on children with hydrocephalus for whom VPS was done with “no control group.” Prior data indicated infection rate after VPS surgery of 4% [2]. Applying Dobson’s formula for sample size calculation [4] and adjusting for a 5% contingency, the minimum required sample for the study was 62 subjects. A total of 68 children were included in the pilot cohort study (Harare), 94 cases in Oshakati, and 47 children in Lubumbashi hospitals.

### Procedure (patient management)

Patients with hydrocephalus indicated for shunting were booked for surgery after anesthetic clearance. They were operated through the classic VP Shunt insertion technique and the protocol adopted for shunt implantation is as in Table 1.

### Measurement of variables

Prematurity was defined as a gestational age of less than 36 weeks from last normal menstrual period or ultrasound determined estimated gestational age less than 36 weeks at delivery. The nutritional status of the children was assessed by examination of their “Road to Health Card (RTHC)” [31].

### Outcome measure

Primary outcome was shunt infection at 3 months defined in accordance with the consensus recommendations of the Canadian Pediatric Neurosurgery Study Group [5]. The criteria to diagnose surgical site infection followed the 1999 Centre for Disease Control guidelines [16].

Operating time was calculated from the first skin incision to completion of wound dressing.

### Follow-up

Follow-up was from the time of admission for shunt insertion to 3 months after the shunting operation. The first review was

**Table 1** Protocol to minimize infection

- Shunts done in the morning
- Neonates and infants before older patients
- No shunts done after an operation for an infection
- Patients were shaved with razor on the theater operating table
- Patients' chest, abdomen, and shaved scalp area then thoroughly washed with warm water with povidone-iodine 7.5% surgical scrub to remove gross contamination
- Two 10% povidone-iodine solution skin scrubs before draping. Plastic adhesive draping not used.
- Third skin wash with 10% povidone-iodine solution after draping
- Intermittent application of povidone-iodine 10% (about every 10 to 15 min) on the wound and exposed skin during the procedure to keep exposed skin moist
- Prophylactic antibiotic given at induction of anesthesia
- Wherever possible efforts made to limit number of incisions to two, viz abdominal and scalp
- Double gloving and change of gloves prior to handling shunt hardware
- Shunt opening delayed to time immediately before insertion
- Meticulous and minimal shunt handling
- Abdominal catheter pulled down from scalp into pre-fashioned subcutaneous tunnel to abdominal incision and wrapped in sterile towel avoiding contact with skin
- Ventricular catheter placed into ventricle and cerebrospinal fluid sample collected immediately
- Ventricular and abdominal catheters connected
- Abdominal catheter assessed for flow then immediately implanted into peritoneal cavity
- Meticulous hemostasis secured
- Antibiotics continued to day 3 post-shunt insertion
- Sterile dressing removed on day 3 post-shunt insertion
- Patients discharged typically on day 2 to 4 post-shunt insertion
- Pressure on shunt avoided at all times
- Dressing is changed on a daily basis until removal of stitches

at day 10, then at 6 weeks, and finally at 3 months post-operation during which they were checked for shunt infection in addition to classic clinical routines. When necessary, telephone calls were made to remind parents of pending outpatient review dates.

### Data collection

Data was collected by the respective country investigators using a questionnaire designed and adapted for the study.

### Statistical analysis

Analysis was done using STATA/MP version 13.0.

### Ethical clearance

Authority to perform the study was obtained from the Joint Research and Ethics Committees of the hospitals.

## Results

A total of 211 shunt insertion procedures performed on 209 children were analyzed. One male and female had 2 separate shunt insertion procedures during the study period. There was one loss to follow-up (Fig. 1).

The median age of the participants was 9 months (p25 = 6 months p75 = 14 months) (min. 2 months and max. 59 months).

There were 84 males and 125 females and were all Africans. Two patients (2.56%) were delivered prematurely and had no antecedent history of surgery to treat hydrocephalus secondary to intraventricular hemorrhage of prematurity.

The mean weight  $\pm$  standard deviation (SD) was  $8.76 \pm 2.58$  kg. The majority ( $n = 180$  of 209) of children had a normal growth trajectory (between  $\pm 2$  SD lines). Twenty-seven (21.0%) had a weight-for-age below 2 SD. Breast-feeding was documented in 109 (95.2%) children (Table 2).

### Type and etiology of hydrocephalus

Hydrocephalus was non-communicating in 72.0% ( $n = 152$ ). Aqueductal stenosis was the most frequent cause for non-communicating hydrocephalus in 84.9% ( $n = 129$ ). Post-infectious HCP accounted for 44.1% ( $n = 26$ ) of communicating HCP cases (Table 2).

### Operative factors

The median pre-operative hospital stay was 1 day (IQR 1–2 days). All the children had Chhabra shunts (Surgiwear Ltd., India) implanted using the protocol.

In 90.5% children ( $n = 191$ ), the surgeries were performed in the morning. In 4.7% of the shunts, the surgery was done emergently. Most children (91%) were having their first shunt implanted.

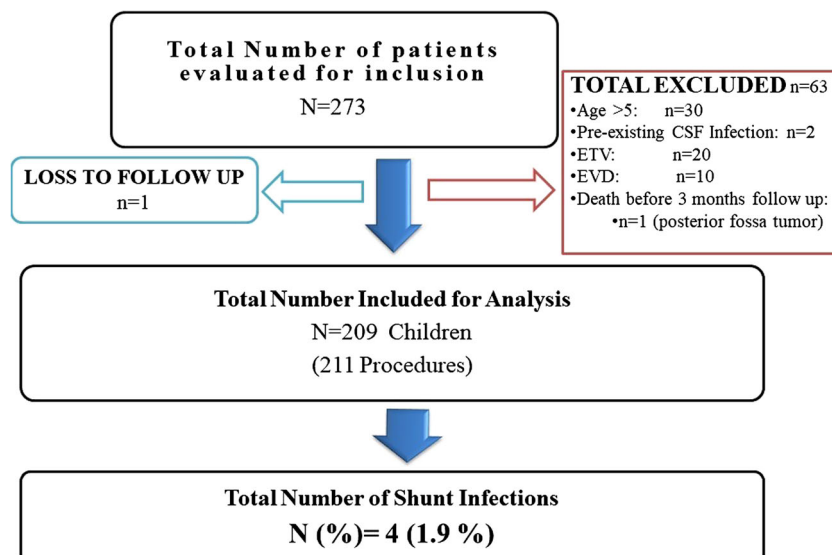
The median duration of surgery was 65 min (IQR from 60 to 85 min). The mean number of persons in the theater during the operations was 8.22 (SD 2.86) (for Harare) (Fig. 2).

For Harare, 57 (71.3%) of the shunts were done by surgeons in their 3rd year of surgical training, and 7 (8.8%) by a consultant neurosurgeon. For the other two centers, a consultant neurosurgeon did all the surgeries (Table 3).

### Outcome

Shunt infection was diagnosed in four children giving an infection rate of 1.9% ( $n = 4$ ) (95% CI 0.7 to 5.0%) per procedure. The infection rate was 2.94% in Harare, 2.13% in Oshakati, and 0% in Lubumbashi hospital. The median time to develop infection was 8.5 days (p25 = 5 and p75 = 12) (Fig. 3).

Fig. 1 Patient flowchart



Case no. 1: A 2-month old with post-infectious communicating hydrocephalus. The infecting organism isolated from both peri-shunt tissues and CSF from a shunt tap was *Staphylococcus aureus*. The clinical findings were a perisubcutaneous shunt path abscess which complicated into meningitis and ventriculitis. This infection developed 10 days after shunt implantation.

Case no. 2: A 7-month old, with congenital communicating hydrocephalus. A mixed infection consisting of gram-negative rods of both lactose fermenting and non-lactose fermenting coliforms was causal. Presentation of this infection was 2 weeks from shunt implantation.

Case no. 3 was cases of post-infectious hydrocephalus and case 4 Chiari type 2.

They were respectively 3 and 4 months old. *Staphylococcus aureus* was detected in both cases. The children were treated by removal of the shunt, insertion of external ventricular drainage, and sensitivity-guided antibiotic therapy followed by successful reimplantation of the VPS.

### Other post-operative complications

A temporary post-operative CSF leaks developed in 2 children and a stitch abscess in one other child (not the children with shunt infections). CSF leak resolved spontaneously and stitch abscess cleared with stitch removal and application of anti-staphylococcal ointment.

### Risk factors for shunt infection

The low number of established infections in this study precluded the statistical subgroup analysis of risk factors to allow identification of local risk factors.

## Discussion

Hydrocephalus is a common neurosurgical problem in the pediatric age group [10] [28]. VPS is the mainstay in the treatment of a significant proportion of children with hydrocephalus. Among VPS complications, infection continues to be a serious cause of shunt failure; is the major source of morbi-mortality, an important contributor to the cost of care and a true frustrating problem for clinicians [1].

Several protocols have been developed and implemented over the years to curb shunt infection [2, 12, 13, 20, 22, 26, 27] but only very few centers in the world have achieved infection rate below 1% [28]. These centers employ precautions that are difficult to replicate in most hospitals especially in developing countries and teaching hospitals with trainees [1].

Following the strict adoption and implementation of our aforementioned protocol (Table 1), we observed an infection rate of 1.9% per procedure validating the previous retrospective established rate of 3.5% [22] in the same setting (Table 1). Our findings mirror those of Mottolese et al. (infection rate of 2.8%) [20], albeit higher than those of Choux et al. (0.17%) [2] and Pirotte et al. (< 1%) [26] but favorably comparable with those of Rotim et al. (5.3%) [27], Kestle et al. (3.8%) [12], and 5.7% for hospitals forming the Hydrocephalus Clinical Research Network Quality Improvement Initiative [13]. Sibanda et al. in 1991 had reported a rate of 13.2% in a period where there was no documented protocol [30].

Our observed rate in between the low outliers and the lower figure of world averages challenges the notion that these low rates can only be achieved in well-resourced settings as suggested by their physical location. The common thread running through all these low outliers is the application of institution-specific peri-operative protocols culminating to reduction in shunt infection rates.



**Table 2** Characteristics of patients

Parameter	Zimbabwe (Harare University Hospitals) <i>n</i> = 68	Namibia (Oshakati Hospital) <i>N</i> = 94	DR of Congo (Lubumbashi Hospital) <i>n</i> = 47
Age			
• Median (p25 p75) (min max)	9 (6 14) (2 59)	6.4 (4 9.3) (1 60)	36 (12 60) (1 60)
Sex: M:F	33:35	21: 73	30:17
Term of pregnancy			
• Preterm	2 (2.9)	3 (3.2)	0 (0)
Race			
• Africans	68 (100)	94 (100)	47 (100)
Weight for age			
• > + 2 SD	2 (2.9)	0 (0)	0 (0)
• Normal	57 (83.8)	82 (87.2)	41 (85.1)
• < - 2 SD	9 (13.2)	12 (12.8)	6 (14.9)
Breast-feeding status			
• Yes	66 (97.1)	88 (93.6)	45 (95.7)
Diagnostic tool			
• CT scan	12 (17.6)	88 (93.6)	46 (97.9)
• CT scan/MRI	0	5 (5.3)	0 (0)
• Sonography	56 (82.4)	1 (1.1)	1 (2.1)
Type/etiology of hydrocephalus			
• Non-communicating	46 (65.7) <sup>†</sup>	74 (78.7)*	32 (68.1) <sup>§</sup>
• Communicating	24 (34.3) <sup>††</sup>	20 (21.3)**	15 (31.9) <sup>§§</sup>

<sup>†</sup> Congenital aqueductal stenosis = 41, tumor = 5

<sup>††</sup> Post-infectious = 18, myelomeningocele = 3, post-traumatic = 3

\*Congenital AS = 68, DWS = 1, tumors = 5 (CPP = 2, MB = 1, PA = 2)

\*\*Myelomeningocele = 5 (one ruptured), post-meningitis = 3, unknown = 12

<sup>§</sup> Aqueductal stenosis = 20, tumors = 7, DWS = 5

<sup>§§</sup> Myelomeningocele = 9, post-infectious = 5, unknown = 1

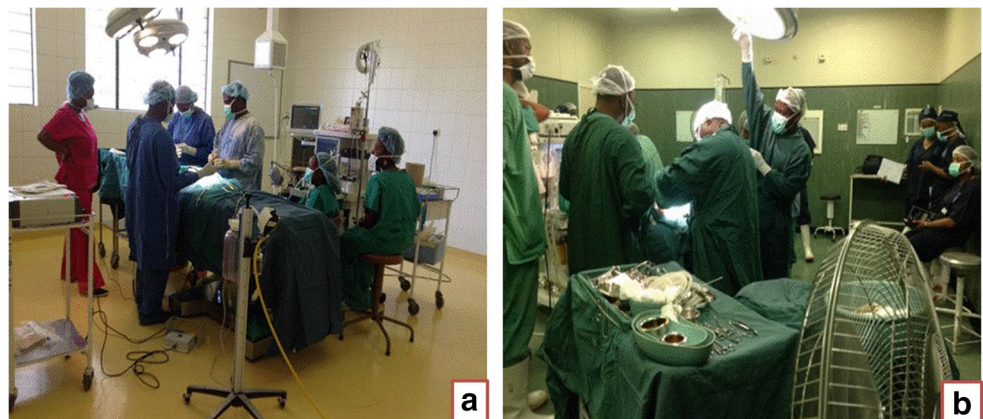
NB: for Harare there were 68 children but 70 shunt procedures

The rationale behind these protocols has been the realization that most shunt infections occur within 3 months post-surgery thus are a result of peri-operative factors which could be mitigated by the application of these protocols [2]. Varied as these protocols are, a common theme found among them is the need for limited shunt hardware handling, delayed

opening of the shunt prior to implantation, and avoidance of contact of shunt with skin. All other measures instituted vary from protocol to protocol (Table 4).

Some of the measures are difficult to implement in low-income settings as ours, viz limited operating room traffic, skin preparation with chlorhexidine, and choice of surgeon.

**Fig. 2** A theater scene for shunt insertion with a consultant and trainees. **a** Without students. **b** With students



**Table 3** Operative factors

Parameter	Zimbabwe (Harare University Hospitals)	Namibia (Oshakati Hospital)	Democratic Republic of Congo (Lubumbashi Hospital)
<i>n</i>	68	94	47
Pre-hospital stay			
• Median (p25 p75)	1 (p25 = 1 p75 3)	1 (1 3)	1 (1 2)
Number of surgeries			
• First	62 (88.6)	84 (89.4)	46 (97.9)
• Second	7 (10.0)	9 (9.5)	1 (2.1)
• Third	1 (1.4)	1 (1.1)	0
Chhabra (Surgiwear India)			
• Yes	68 (100)	94 (100)	47 (100)
Persons in the OR			
• Mean ± SD	8.2 ± 2.9	5	4
Surgeon's experience			
• Third year	57 (71.3)	0	0
• Fourth year	15 (18.8)	0	0
• Consultant	7 (8.8)	94 (100)	47 (100)
Surgery type			
• Elective	69 (98.6)	92 (97.9)	47 (100)
• Emergency	1 (1.4)	9 (2.1)	0 (0)
Timing of surgery			
• Morning	62 (88.6)	85 (90.4)	44 (93.6)
• Afternoon	8 (11.4)	9 (9.6)	3 (6.4)
Duration of surgery			
• Median (p25 p75)	85.6 (60 100)	65 (50 75)	60 (55 68)
Infection rate	2/68 = 2.94%	2/94 = 2.13%	0/42 = 0%

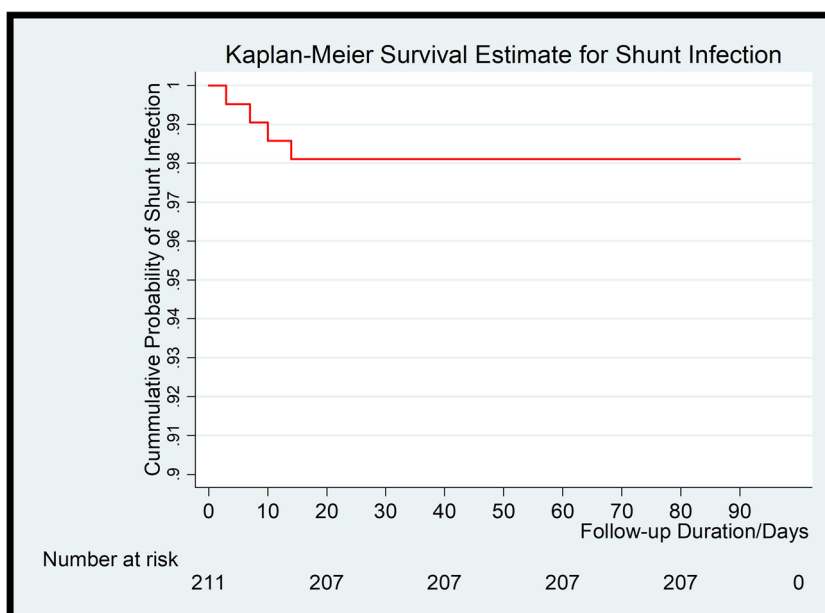
However, the effectiveness of our protocol suggests that despite our resource restraints, the protocol captured the critical elements necessary to have a significant impact on the infection rate.

The limitation of persons in theater and restriction of traffic into and out of theater is difficult to implement because our institution is a university training center (for Harare). In the absence of intraoperative audiovisual aids to demonstrate procedures, it is customary to have numerous students in theater

taking turns to observe proceedings during shunt implantation (Fig. 3); a scenario contrary to the recommendations of other protocols [2, 12, 13, 20, 26, 27].

Another notable deviation from international norms is the continued use of 10% povidone-iodine solution to prepare the patient's skin prior to draping and its intermittent reapplication intraoperatively instead of chlorhexidine solutions. It has been well established that bacterial skin recolonization from the sweating gland occurs after about 30 to 45 min. Chlorhexidine has

**Fig. 3** Kaplan Meier survival for shunt infection. The infection rate was 1.9% ( $n = 4$ ). The median time to develop infection was 8.5 days



**Table 4** Summary of comprehensive protocols for shunt infection control in children

Author (year)	Study design	Level of evidence	Surgeries	Intervention	Outcome for shunt infection Pre-protocol→ post-protocol
Kalangu (2019) [11]	Prospective cohort	3	70	See Table 1	Reduced 13.2 via 3.5 to 1.9% (ARR 11.3%)
Kestle (2011) [13]	Prospective cohort with historical control	3	1571	Protocol: limit OR traffic, surgical site away from OR door, chloraprep 3 min dry time, double glove, I oban™ drape, shunt reservoir, vancomycin/gentamicin injection	Reduced 8.8 to 5.7% (ARR 3.1%, RRR 35.2%), $p = 0.003$
Pirotte (2007) [26]	Prospective cohort	3	115	Protocol: no scrub nurse, double glove, open abdomen first, no touch, close cranium first, OR time < 30 min, limit OR traffic, schedule as first procedure	Shunt infection < 1%
Mottolese (2000) [20]	Retrospective cohort with historical control	4	70	Choux's protocol + change from Holter to Medos valve	Reduced 6.4% → 2.8% (ARR 3.6%, RRR 56.3%), no statistic
Rotim (1997) [27]		4	112	Protocol: schedule in morning, limit traffic, glove change prior to implant, OR time < 40 min, post-operative IV vancomycin	Reduced 9.4% → 5.3% (ARR 4.1%, RRR 43.6%), no statistic
Kestle (1993) [12]		4	576	Modified Choux's protocol	Reduced 12.9% → 3.8% (ARR 9.1%, RRR 70.5%), $p < 0.001$
Choux (1992) [2]		4	1197	Choux's protocol*	Reduced 7.8% → 0.17% (ARR 7.6%, RRR 97.4%), no statistic

\*Protocol: prep hair wash (betadine), no shave, schedule in morning, neonates first, OR time 20–40 min, 4 OR personnel, no scrub nurse, shunt irrigated with gentamicin, post-operative day 1 hair wash

been proven to be a better skin antiseptic with a more durable action [28]. Our protocol required that 10% povidone-iodine solution be intermittently applied to keep the peri-incisional skin of the operative sites moist to ensure continued suppression of skin microbial contaminants. Thus, chlorhexidine's superiority over 10% povidone-iodine solution's clinical relevance is brought into question as a low infection rate using the less than ideal solution was still achieved. The inference to be made is that the purported inferior action of 10% povidone-iodine solution is still effective enough to ensure low infection rates when combined with meticulous surgical technique. Povidone-iodine (10%) solution therefore seems to be a reasonable alternative when chlorhexidine is either not readily available or unaffordable.

Our average duration of surgery was longer than the recommended time of surgery for protocols in institutions having an infection rate of less than 1% and all but 7 of the procedures were performed by consultants (for Harare). This is in stark contrast with the Choux and the Pirotte protocols where the procedures were done by a senior neurosurgeon and a single senior neurosurgeon, respectively [2, 26]. Despite our observed rate not as low as that reported by them, the pivotal role played by the observance of surgical technique is emphasized in reducing occurrence of infections [2, 26]. With the foregoing considered the corresponding influence of seniority on the development of shunt infection is subsequently subdued.

It was noted that 95.2% of the children were breast-feeding, a factor that may have positively influenced the results obtained in accord with the protective effect of breast-feeding for children under the age of 6 months [24]. However, our study population was generally older ( $p_{50} = 9$  months).

Another peculiarity of this study was the positive effect on shunt infection by the short pre-surgery and post-surgery hospital stays. A more aggressive approach of discharging patients between day 2 and 4 post-operatively was adopted in our protocol that may have contributed to our lower infection rates.

An expected preponderance of congenital and post-infectious hydrocephalus in a developing setting formed the study population. There were 17 children in our study with myelomeningocele, an unexpected low number compared with a previous study in the same setting [30]. Given the establishment of myelomeningocele as a risk factor for shunt infection, the inclusion of a higher proportion of subjects with this risk factor inter alia the absence of a set protocol possibly explained the higher infection rates of 13.2%; they [30] observed and a lower infection rate (1.9%) in this study.

Non-measured factors worth mentioning as they may have positively influenced the results obtained are the education about shunt infection that was routinely given to caregivers during informed consent. Additionally, reciprocal phone calls between the principal investigator and parents, the closer follow-up, may have led to more vigilance and prevention of infection beyond the immediate peri-operative period. This period was noted to be a time when the patients would still be vulnerable to contamination leading to shunt infection [32].

A closer look at the 4 children with shunt infection shows that three were undernourished, 2 had post-infectious hydrocephalus and another Chiari type 2. The aforementioned considered together put these children at an inherently increased risk of shunt infection. Furthermore, the development of the infections within a month of surgery makes them direct

complications of surgery. The cases of infection were potentially avoidable if surgery had been delayed to optimize the patients.

The strength of our study was in its design: Our cohort study just like that of Pirotte et al. [26] and Kestle et al. [13] was prospective providing level 3 evidence. Previous protocols were of a lower level of evidence (level 4) because they were retrospective and used historical controls [2, 12, 20, 26, 27]. Selected comprehensive protocols for shunt infection control in children [2, 12, 13, 20, 26, 27] are summarized in Table 4.

**Study limitations:** The main limiting factor of the study was the sample size given the low infection rate obtained that did not allow for statistical analysis and verification of risk factors. As a result, no justifiable modification of the protocol can be made based on the findings of this study. Adjunctive anthropometric measurements of the nutritional state of these hydrocephalic children such as the mid-arm circumference and skinfold thickness combined with clinical assessments of the skin, hair, and muscle bulk would have been more appropriate. These adjuncts would expose falsely normal or accelerated growth curves due to pathologically increasing CSF as opposed to general body weight gain. This effect was not catered for in the study.

The durability of the results after the 3-month follow-up compared with the lengthier follow-ups in other series may be questioned. However, the findings that 90% of VPS infections occur within 30 days [9] and that a high-risk pediatric population was singled out for analysis mitigate the shortcoming of the short follow-up.

## Conclusion

The institution of a protocol that emphasizes meticulous surgical technique and adherence to antisepsis reduces infection rate comparable with those from well-resourced settings. The main paradigm shift is the acceptance to work in a wet environment of povidone-iodine which eliminates bacterial recolonization of the skin. Continued data collection is recommended as it will allow identification of locally significant risk factors. This information will facilitate the modification of the protocol to control for the factors and assist in further reduction of shunt infections and their sequelae.

## Compliance with ethical standards

**Patient consent** The patient or guardian has consented to this study by signing the consent form.

**Conflict of interest** None.

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