

# Morbidity, Mortality and Treatment Failure after Endoscopic Third Ventriculostomy with Choroid Plexus Cauterization in Infants: A Retrospective Study of 120 Cases at Bouaké University Hospital, Côte d'Ivoire

Faozo Stephane Landry Teti<sup>1,2\*</sup>, Koffi Yves Soress Dongo<sup>1,2</sup>, Yao Bernard Fionko<sup>1,2</sup>, Kouadio Jean-Baptiste Keke<sup>1,2</sup>, Keableon Louis Aymar Derou<sup>1,2</sup>, Aderehime Haidara<sup>1,2</sup>

<sup>1</sup>Department of Neurosurgery, Bouaké University Hospital, Bouaké, Côte d'Ivoire

<sup>2</sup>Faculty of Medical Sciences, Alassane Ouattara University, Bouaké, Côte d'Ivoire

Email: \*landjoss1990@gmail.com

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## Abstract

**Background:** Endoscopic third ventriculostomy combined with choroid plexus cauterization (ETV + CPC) is a major alternative to ventriculoperitoneal shunting in infants in sub-Saharan Africa. Its efficacy is well documented, but its own morbidity far less so. **Objective:** To describe the complications, their timing and severity, treatment failures, reoperations and mortality after ETV + CPC in a West African university hospital. **Patients and Methods:** A single-centre retrospective study of 120 consecutive infants aged 24 months or younger, operated on between 1 January 2024 and 30 April 2026. The endpoints were postoperative complications graded according to the Clavien-Dindo classification, their time to onset, treatment failure, reoperation, shunt-free survival (Kaplan-Meier) and mortality, with attribution to the procedure established case by case. Proportions are reported with exact 95% confidence intervals. **Results:** Seventeen patients (14.2%; 8.5 - 21.7) had at least one postoperative adverse event, amounting to 18 events—the five deaths being included as Clavien-Dindo grade V—with a median time to onset of 8 days; 77.8% occurred within 30 days, but the six secondary stoma obstructions were spread from day 21 to the eighth month. Of four cases of meningitis (3.3%), three were healthcare-associated (2.5%) and one was intercurrent and community-acquired (*Neisseria meningitidis*). Nine patients (7.5%) were reoperated on: six shunts and three endoscopic revisions. Shunt-free survival was 92.7% at twelve

months. Mortality was 4.2% (1.4 - 9.5); a single death (0.8%) was attributable to the procedure, three were of indeterminate cause and one followed inter-current community-acquired meningitis. **Conclusion:** Morbidity was moderate and mortality rarely attributable to the procedure itself. The timing argues for close monitoring during the first month and scheduled follow-up up to one year; the attribution of infections must be established case by case where community-acquired meningitis is endemic.

## Keywords

Infant Hydrocephalus, Endoscopic Third Ventriculostomy, Choroid Plexus Cauterization, Postoperative Complications, Sub-Saharan Africa

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## 1. Introduction

Infant hydrocephalus is one of the most common paediatric neurosurgical conditions, and its burden falls disproportionately on sub-Saharan Africa, where the incidence of congenital hydrocephalus is estimated at 145 per 100,000 live births versus 68 in North America [1]. Recent African series confirm both the scale of the surgical need and the diversity of aetiologies across the continent [2]-[4].

Ventriculoperitoneal shunting remains the reference treatment, but it creates permanent dependence on implanted hardware. In sub-Saharan Africa, the reported rates of shunt infection and malfunction alone justify the search for alternatives: Gathura *et al.* report poor hardware survival in Kenya [5], and a Ugandan randomized trial found a substantial infectious risk regardless of the valve model used [6].

Endoscopic third ventriculostomy combined with choroid plexus cauterization (ETV + CPC), developed and disseminated by Warf in Uganda, durably treats a substantial proportion of infants without implanted hardware [7]-[10]. Its efficacy has been extensively studied, including in a meta-analysis of 1918 infants [11]. Its own safety profile is far less documented: most publications report success or failure rates without detailing the nature of the complications, their timing, their severity or their actual attribution to the procedure. Yet where access to paediatric intensive care and follow-up imaging is limited, this description determines the organization of postoperative monitoring.

The aim of this work was to describe the postoperative complications, their timing and severity, treatment failures, reoperations and mortality observed after ETV + CPC in infants at Bouaké University Hospital, Côte d'Ivoire.

## 2. Patients and Methods

### 2.1. Study Design and Population

A single-centre retrospective descriptive study was conducted in the neurosurgery

department of Bouaké University Hospital (Côte d'Ivoire) over 28 months, from 1 January 2024 to 30 April 2026. Reporting follows the STROBE recommendations for observational studies [12].

This cohort is also the subject of four companion analyses, none of which was submitted at the time this manuscript was written: the preoperative profile, the clinical outcomes with an economic evaluation against shunting, the preoperative factors associated with success, and the development of the neuroendoscopy programme. They are therefore not cited, and the authors undertake to share the current versions with the editorial office on request. The present work addresses only morbidity, mortality and failure, and reproduces no primary result of the companion works; the patients, the period and the inclusion criteria are identical across the five analyses. A delineation of the variables, endpoints and analyses unique to each of the five manuscripts is provided in Supplementary **Table S1**, and the companion works will be cross-referenced once available, in line with ICMJE guidance on overlapping publications.

## 2.2. Inclusion and Non-Inclusion Criteria

**Inclusion:** Infants aged 24 months or younger, hydrocephalus confirmed on imaging, treated by ETV + CPC, with a usable medical record and documented post-operative follow-up. The diagnosis was based on ventricular dilatation on transfontanellar ultrasound, computed tomography or magnetic resonance imaging, together with clinical signs of raised intracranial pressure or an increasing head circumference. Recruitment was exhaustive over the study period.

**Non-inclusion:** Incomplete medical record, unusable preoperative imaging, or death occurring before assessment of the treatment outcome from a cause unrelated to hydrocephalus or to the procedure. No minimum follow-up duration was required; the consequences are reported in the Results and discussed in the Strengths and Limitations. Procedures converted intraoperatively to shunting were excluded by design, the analysis being restricted to completed ETV + CPC; the treatment-attempt denominator is reported in Section 3.1.

## 2.3. Operative Technique

ETV + CPC was performed under general anaesthesia with a flexible KARL STORZ neuroendoscope. Antibiotic prophylaxis with ceftriaxone was administered before skin incision. After a paramedian precoronal burr hole and ventricular catheterization, cerebrospinal fluid was systematically sampled for cytobacteriological analysis; the floor of the third ventricle was fenestrated at the centre of the triangle formed by the mammillary bodies and the infundibular recess with a monopolar Bugbee electrode, and the Liliequist membrane was opened to secure communication with the basal cisterns. Choroid plexus cauterization was then performed with monopolar current from the foramen of Monro to the tip of the temporal horn on both sides, with endoscopic septostomy where required, following the technique described by Warf. Closure comprised the dura where feasible, then the

galea and subcutaneous plane with resorbable suture and the skin with interrupted or running suture; the burr hole was occasionally plugged with Surgicel. After each procedure, the instruments underwent a standardized high-level reprocessing protocol. Postoperatively, patients were monitored on the ward with a vital-signs chart and daily clinical examination, received analgesia and hydro-electrolyte support and antibiotic prophylaxis continued for 48 hours, and had head circumference measured daily for five days before discharge. Postoperative imaging was not systematic and was obtained only when clinically indicated.

## 2.4. Definitions

**Postoperative complication:** Any adverse event occurring after the procedure and documented in the record during follow-up. The count distinguishes the patients who had at least one complication from the total number of events, an initial event being able to give rise to a further complication itself. The date of onset of each event was recorded.

**Severity:** Complications were graded retrospectively from the records according to the Clavien-Dindo classification [13]: I, symptomatic treatment or simple monitoring; II, pharmacological treatment, chiefly antibiotics; IIIa, procedure without general anaesthesia; IIIb, procedure under general anaesthesia; IVa and IVb, organ failure with survival; V, death.

**Postoperative meningitis and attribution:** Any meningitis diagnosed after the procedure was recorded, in the presence of an infectious syndrome with suggestive cerebrospinal fluid (CSF), with or without bacteriological identification. A case was classified as confirmed healthcare-associated infection when meningitis occurred more than 48 hours after the procedure together with an operative portal of entry (CSF leak or wound infection) or a nosocomial organism; as probable healthcare-associated infection when the temporal and clinical picture fitted a care-related infection, but no organism was isolated (antibiotic therapy having been given before lumbar puncture); and as intercurrent community-acquired meningitis when there was no breach or operative-site abnormality and the organism was a recognized community pathogen. The classification took into account the time to onset, the organism, the presence of a breach or an abnormality of the operative site, and the local epidemiological context. This case-by-case distinction is necessary in a region belonging to the African meningitis belt, where community-acquired meningitis may occur in a recently operated infant with no connection to the procedure.

**Secondary stoma obstruction:** Recurrence or worsening of signs of raised intracranial pressure after an initial improvement, with confirmation at reoperation or, failing that, on imaging of the non-functional nature of the stoma.

**Treatment failure:** The need for a further operation for hydrocephalus, absent or only transient clinical improvement, or death during follow-up—the definition used in the companion works on the same cohort. Failure and complication are not equivalent: a complication may resolve without failure, and a failure may oc-

cur without any recorded complication.

**Mortality:** Overall postoperative mortality covers all deaths occurring during follow-up. Attribution was classified as direct (death from an intraoperative technical complication), indirect (death from a postoperative complication of the procedure), indeterminate (a death whose relationship to the procedure or to perioperative care could not be established or excluded from the records) or not attributable (no link with the procedure, including death from an intercurrent community-acquired condition). The attribution of infections and deaths was adjudicated independently by two authors, a neurosurgeon and an anaesthesiologist, using the clinical, microbiological and temporal criteria described above, which were defined before adjudication. Any disagreement was resolved by consensus.

## 2.5. Data Analysis

Categorical variables are expressed as counts and percentages with a 95% confidence interval (CI) computed by the exact Clopper-Pearson method; quantitative variables as mean and range, or median and range.

Shunt-free survival was estimated by the Kaplan-Meier method [14]. The event was placement of a secondary ventriculoperitoneal shunt; endoscopic revisions were not counted as events, with the patient remaining free of implanted hardware. Patients were censored at their last consultation or at death—a convention that treats death as censoring whereas it constitutes a competing risk, which is discussed in the Strengths and Limitations.

No comparative analysis was undertaken: the number of events, of deaths in particular, did not allow associations to be estimated with acceptable power. All analyses were performed in Python 3.12 (NumPy 2.4, SciPy 1.17); the exact binomial confidence intervals were obtained from the Beta quantile function (`scipy.stats.beta`).

## 2.6. Ethical Considerations

The study was conducted in accordance with the Declaration of Helsinki (2013 revision). Because Bouaké University Hospital had no constituted ethics committee during the study period, the study was initially authorized by the head of the Department of Neurosurgery and by the hospital management. It subsequently received retrospective approval from the Institutional Ethics Committee of Bouaké University Hospital (approval No. CEI/CHU-BKE/106/2026, 14 June 2026). Written informed consent was obtained from the parents or legal guardians at the time of care, and all data were anonymized before analysis.

# 3. Results

## 3.1. Population and Follow-Up

One hundred and sixty-three hydrocephalic infants were assessed during the study period; 40 were referred directly for shunting or judged ineligible for neuroendoscopy, 123 were taken to the operating theatre, and 3 procedures were in-

interrupted intraoperatively and converted to shunting. The 120 completed endoscopic third ventriculostomies constitute the population analysed here. Of the 123 attempted procedures, intraoperative conversion to shunting occurred in 3 (2.4%); the indications were an unfavourable anatomy of the third-ventricle floor, with landmarks judged insufficiently reliable to perform the ventriculostomy safely, in one case; thick and opaque prepontine membranes preventing a communication judged safe with the basal cisterns in one case; and intraoperative intraventricular bleeding that durably impaired endoscopic visibility and led to interrupting the procedure as a precaution in one case, the bleeding being controlled without basilar trunk injury or documented intraoperative deficit. Intraoperatively, minor bleeding controlled by Ringer's lactate irrigation was recorded in 11 of the 120 completed procedures (9.2%)—from prepontine cistern vessels in 6, choroid plexus in 4 and cortico-dural veins in 1—with no basilar trunk injury. Choroid plexus cauterization was bilateral in 117 infants (97.5%) and covered 80% - 100% of the accessible plexus in 100 of the 117 bilateral procedures (85.5%). The mean age was 7.6 months (range 21 days to 24 months) and 73 patients (60.8%) were male. Aqueductal stenosis was the predominant cause (77; 64.2%), ahead of Dandy-Walker malformation (21; 17.5%), post-meningitic hydrocephalus (10; 8.3%) and myelomeningocele (10; 8.3%); the cause remained undetermined in 2 patients (1.7%). The general characteristics are presented in **Table 1**.

**Table 1.** General characteristics of the 120 infants treated by endoscopic third ventriculostomy with choroid plexus cauterization.

| Characteristic                             | n                                   | %          |
|--------------------------------------------|-------------------------------------|------------|
| <b>Age at surgery</b>                      |                                     |            |
| Mean (range)                               | 7.6 months<br>(21 days - 24 months) | —          |
| <b>Sex</b>                                 |                                     |            |
| Male                                       | 73                                  | 60.8       |
| Female                                     | 47                                  | 39.2       |
| <b>Cause of hydrocephalus</b>              |                                     |            |
| Aqueductal stenosis                        | 77                                  | 64.2       |
| Dandy-Walker malformation                  | 21                                  | 17.5       |
| Post-meningitic hydrocephalus              | 10                                  | 8.3        |
| Myelomeningocele                           | 10                                  | 8.3        |
| Undetermined                               | 2                                   | 1.7        |
| <b>Ventricular morphology</b>              |                                     |            |
| Triventricular                             | 77                                  | 64.2       |
| Tetraventricular                           | 43                                  | 35.8       |
| <b>Previous ventriculoperitoneal shunt</b> | <b>3</b>                            | <b>2.5</b> |

**Continued**

| <b>Preoperative imaging</b> |            |              |
|-----------------------------|------------|--------------|
| CT alone                    | 86         | 71.7         |
| Ultrasound and CT           | 28         | 23.3         |
| CT and MRI                  | 6          | 5.0          |
| <b>Total</b>                | <b>120</b> | <b>100.0</b> |

CT: computed tomography; MRI: magnetic resonance imaging; ultrasound: transfontanelar ultrasound. The five aetiological categories and the two ventricular morphologies are mutually exclusive.

Ninety-two patients (76.7%) were reviewed several times, with a mean of two consultations and up to four; 26 (21.7%) were seen only once, one month after surgery, and 2 (1.7%) were lost to follow-up. Five patients died between the first and the twentieth postoperative day, so that their observation ended before one month, and the stated interval of 30 days to 2 years, for a mean of 7.5 months, applies only to the others. The date of the last visit was not recorded: at least 28 patients (23.3%) had no assessment beyond the first postoperative month, and the individual follow-up of the other 92 is not documented. The crude rates below must therefore be read as minimum estimates, which is why shunt-free survival is also presented as a Kaplan-Meier estimate. Follow-up was not governed by a fixed schedule and imaging was obtained only on clinical indication; unless otherwise stated, the event dates reported below correspond to the documented onset of symptoms or clinical presentation that led to diagnosis, rather than detection during scheduled surveillance. Individual follow-up durations beyond the first month were not systematically recorded (mean approximately 7.5 months among survivors); a median, interquartile range and exact 6- and 12-month follow-up proportions therefore cannot be derived, and the unequal follow-up is handled by the time-to-event analyses (Kaplan-Meier and competing-risk cumulative incidence, Section 3.4).

### 3.2. Overall Postoperative Morbidity and Timing

Seventeen patients had at least one postoperative adverse event, an all-cause morbidity of 14.2% (95% CI: 8.5 - 21.7), for a total of 18 events. Fourteen patients (11.7%; 6.5 - 18.8) had a recorded complication accounting for 15 of these events (**Table 2**); one of them had a CSF leak subsequently complicated by meningitis, and all the others a single event. Three further patients, and three further events, were early neurological or anaesthetic deteriorations that proved fatal and gave rise to no other recorded complication; by the definition adopted, these are counted as adverse events and graded V, so that all five deaths appear in the all-cause and grade-V tallies. Complications and mortality attributable to the procedure are reported as a secondary outcome (Sections 3.6 and 4.2).

Secondary stoma obstruction was the most frequent complication, in 6 patients (5.0%; 1.9 - 10.6), ahead of meningitis in 4 (3.3%; 0.9 - 8.3) and isolated hyperthermia in 2 (1.7%; 0.2 - 5.9); CSF leak, superficial wound suppuration and strabismus

each occurred in 1 patient (0.8%; 0.0 - 4.6). The complications, their time to onset, their management and their Clavien-Dindo grade are presented in **Table 2**.

**Table 2.** Postoperative complications: frequency, time to onset, management and Clavien-Dindo grade (n = 120).

| Complication                                    | n         | % (95% CI)               | Time to onset                       | Management                                                        | Grade                  |
|-------------------------------------------------|-----------|--------------------------|-------------------------------------|-------------------------------------------------------------------|------------------------|
| Secondary stoma obstruction                     | 6         | 5.0 (1.9 - 10.6)         | Day 21 to month 8                   | Endoscopic revision (3) or ventriculoperitoneal shunt (3)         | IIIb (6)               |
| Meningitis                                      | 4         | 3.3 (0.9 - 8.3)          | Day 6 to day 18                     | Antibiotic therapy; secondary shunt after CSF sterilization (2)   | IIIb (2), V (2)        |
| Isolated hyperthermia                           | 2         | 1.7 (0.2 - 5.9)          | Day 1 and day 2                     | Monitoring and symptomatic treatment                              | I (2)                  |
| Cerebrospinal fluid leak                        | 1         | 0.8 (0.0 - 4.6)          | Day 5                               | Secondary suture under general anaesthesia and antibiotic therapy | IIIb (1)               |
| Superficial wound suppuration                   | 1         | 0.8 (0.0 - 4.6)          | Day 7                               | Local care and antibiotic therapy                                 | II (1)                 |
| Strabismus                                      | 1         | 0.8 (0.0 - 4.6)          | Day 3                               | Monitoring; spontaneous resolution                                | I (1)                  |
| Early neurological or anaesthetic deterioration | 3         | 2.5 (0.5 - 7.1)          | Day 1 to day 7                      | Intensive supportive care; fatal outcome                          | V (3)                  |
| <b>Total events</b>                             | <b>18</b> | —                        | Median 8 days<br>(1 day - 8 months) | —                                                                 | I 3, II 1, IIIb 9, V 5 |
| <b>Patients affected</b>                        | <b>17</b> | <b>14.2 (8.5 - 21.7)</b> | —                                   | —                                                                 | —                      |

Seventeen patients had at least one postoperative adverse event, for 18 events; 14 of them had a recorded complication (15 events, one being a cerebrospinal fluid leak subsequently complicated by meningitis) and three further patients had a fatal early neurological or anaesthetic deterioration. Confidence intervals were computed by the exact Clopper-Pearson method. The five grade-V events are the five deaths. Grades I and II represent 4 of the 18 events (22.2%), grades IIIb and V 14 of 18 (77.8%), *i.e.*, 13 patients (10.8%). No event was grade IIIa, IVa or IVb. CI: confidence interval; CSF: cerebrospinal fluid.

### 3.3. Infectious Complications and Attribution

Four cases of meningitis were diagnosed after the procedure, in infants aged 2 to 12 months, between day 6 and day 18. Their characteristics are presented in **Table 3**.

**Table 3.** The four cases of meningitis diagnosed after surgery: cause of hydrocephalus, time to onset, cerebrospinal fluid, organism, course and attribution.

| Case | Aetiology           | Onset  | Cerebrospinal fluid                                                             | Organism                                           | Course                  | Attribution                     |
|------|---------------------|--------|---------------------------------------------------------------------------------|----------------------------------------------------|-------------------------|---------------------------------|
| M1   | Dandy-Walker        | Day 6  | 1850/mm <sup>3</sup> , 86% neutrophils; 2.40 g/L; 0.22 g/L                      | <i>Escherichia coli</i>                            | Recovery, then shunt    | Confirmed HAI                   |
| M2   | Dandy-Walker        | Day 11 | 920/mm <sup>3</sup> , 78% neutrophils; 1.85 g/L; 0.28 g/L                       | Negative culture                                   | Recovery, then shunt    | Probable HAI                    |
| M3   | Aqueductal stenosis | Day 18 | 3200/mm <sup>3</sup> , neutrophil predominance; 3.10 g/L; collapsed CSF glucose | <i>Neisseria meningitidis</i>                      | Sepsis; death on day 20 | Intercurrent community-acquired |
| M4   | Aqueductal stenosis | Day 9  | 2400/mm <sup>3</sup> , 90% neutrophils; 2.75 g/L; 0.18 g/L                      | Methicillin-sensitive <i>Staphylococcus aureus</i> | Death on day 15         | Confirmed HAI                   |

HAI: healthcare-associated infection. The cerebrospinal fluid is described by cellularity, then protein, then glucose. Case M4 followed a cerebrospinal fluid leak that appeared on day 5. Meningitis, all causes combined: 4 patients (3.3%; 0.9 - 8.3). Healthcare-associated meningitis: 3 patients (2.5%; 0.5 - 7.1).

The first two occurred in infants with Dandy-Walker malformation, on day 6 and day 11, with purulent CSF. Culture isolated *Escherichia coli* in the first case and remained negative in the second, antibiotic therapy having been given before the lumbar puncture. Both recovered on antibiotic therapy and were shunted once the CSF was sterilized; they were classified respectively as confirmed and probable healthcare-associated infection.

The third case occurred in an infant with aqueductal stenosis and was diagnosed on day 18 in the presence of an isolated acute meningeal syndrome, without CSF leak, without wound infection and without any abnormality of the operative site; culture isolated *Neisseria meningitidis* and the course was towards neurological sepsis with death on day 20. In the absence of an operative portal of entry, and given the organism, this case was classified as intercurrent community-acquired meningitis and not as a surgical site infection.

The fourth case followed a CSF leak. One patient (0.8%) with aqueductal stenosis had a CSF leak through the surgical wound on day 5, treated by secondary suture in the operating theatre, under general anaesthesia, with appropriate antibiotic therapy; methicillin-sensitive *Staphylococcus aureus* meningitis developed on day 9 and the patient died on day 15. This is the only confirmed healthcare-associated infection with a fatal course in the series. A superficial wound suppuration was also observed on day 7 in a 22-month-old girl and healed with local care and antibiotic therapy, without reoperation.

Three distinct indicators must therefore be considered: meningitis occurring after the procedure, whatever its cause, 4 patients (3.3%; 0.9 - 8.3); healthcare-associated meningitis, 3 patients (2.5%; 0.5 - 7.1); and infections directly related to the procedure, wound suppuration included, 4 patients (3.3%; 0.9 - 8.3). In a sensitivity analysis classifying the community-acquired episode (case M3) as a healthcare-associated infection, healthcare-associated meningitis would rise to 4 patients (3.3%; 0.9 - 8.3) and procedure-attributable mortality to 2 patients (1.7%; 0.2 - 5.9).

### 3.4. Secondary Stoma Obstruction, Reoperations and Shunt-Free Survival

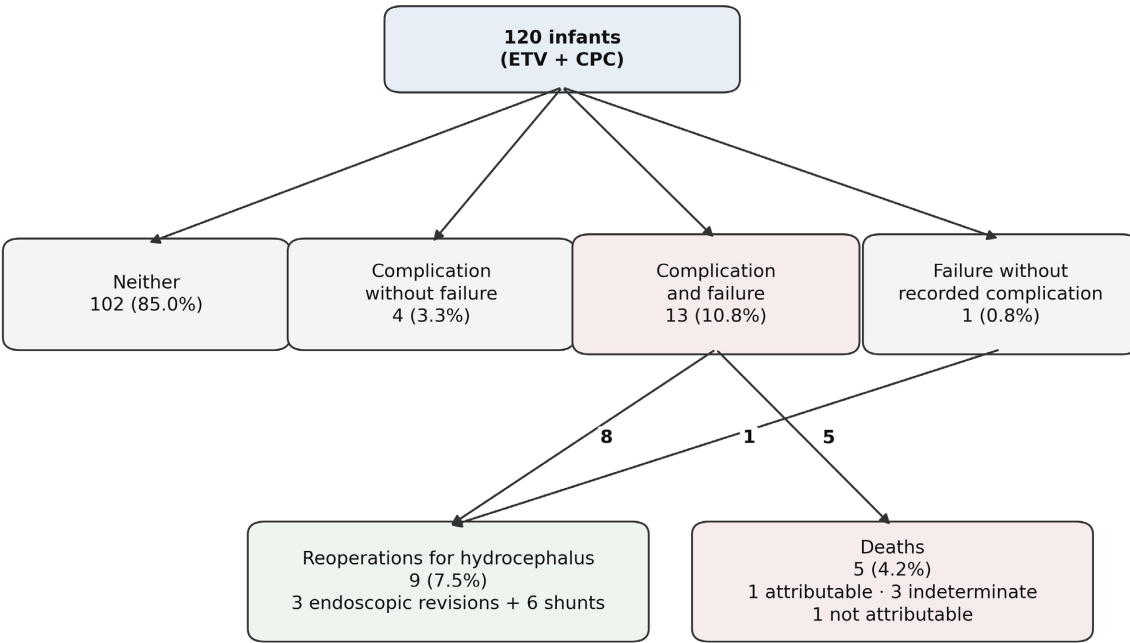
Secondary stoma obstruction was observed in 6 patients aged 3 to 16 months, from day 21 to the eighth postoperative month: five had congenital aqueductal stenosis and one post-meningitic hydrocephalus. Three were treated by endoscopic revision and three by shunting. Obstruction therefore affected 5 of the 77 aqueductal stenoses (6.5%) and 1 of the 10 post-meningitic hydrocephalus cases (10.0%).

Nine patients (7.5%; 3.5 - 13.8) were reoperated on for hydrocephalus: 6 secondary ventriculoperitoneal shunts (5.0%; 1.9 - 10.6) and 3 endoscopic revisions (2.5%; 0.5 - 7.1). The six shunts were placed in the three stoma obstructions not revised endoscopically, in two patients shunted after recovery from healthcare-associated meningitis, and in one patient with Dandy-Walker malformation presenting a symptomatic recurrence without documented obstruction. The three endoscopic revisions, all for stoma obstruction, controlled the hydrocephalus without subsequent shunting during the available follow-up.

Shunt-free survival, estimated by the Kaplan-Meier method, was 97.4% at one month, 96.2% at three months, 94.8% at six months and 92.7% at twelve months, with no further event beyond—an estimate that takes into account the unequal observation durations. In a competing-risk analysis treating death as a competing event, the cumulative incidence of secondary shunting was 2.5%, 3.6%, 5.0% and 7.0% at one, three, six and twelve months (Aalen-Johansen estimator), a shunt-free probability of 93.0% at twelve months that is materially unchanged from the Kaplan-Meier estimate; the cumulative incidence of death was 4.2%, so that event-free survival, alive and free of a shunt, was 88.8% at twelve months. The month-by-month estimates are reported in Supplementary **Table S2**, and the cumulative-incidence curves for secondary shunting and death are shown in Supplementary **Figure S1**.

3.5. Treatment Failures

Fourteen patients (11.7%; 6.5 - 18.8) had a treatment failure: 7 transient clinical improvements, 2 absences of improvement and 5 deaths. Nine of these fourteen patients were reoperated on; the other five were deceased patients, none of whom could be reoperated on beforehand.



All-cause adverse events (complications) = 17 (14.2%); treatment failures = 14 (11.7%).  
Figures on the arrows are patient counts; the three endoscopic revisions are not counted as shunts.

**Figure 1.** Flow diagram of complications, treatment failures and reoperations after endoscopic third ventriculostomy with choroid plexus cauterization in 120 infants. Complications and failures did not concern the same patients: 13 patients had both, 4 had a complication without failure and 1 had a failure without any recorded complication. The three endoscopic revisions are not counted as shunts, with the patient remaining free of implanted hardware. The figures on the arrows are patient counts.

All-cause adverse events (14.2%) and failures (11.7%) overlap only partially (**Figure 1**). Thirteen patients (10.8%) had both: the six stoma obstructions, the two healthcare-associated meningitis cases shunted after recovery, the two fatal meningitis cases and the three early neurological or anaesthetic deaths, all of which count as adverse events. Four (3.3%) had a complication without failure and one (0.8%) had a failure without any recorded complication—a symptomatic recurrence without documented obstruction. One hundred and two patients (85.0%) had neither.

By aetiology, the 10 failures among the aqueductal stenoses (13.0% of this group of 77) were the five stoma obstructions and the five deaths. The 3 failures among the Dandy-Walker malformations (14.3% of 21) were all non-obstructive: two healthcare-associated meningitis cases shunted after recovery and one symptomatic recurrence that was shunted. The single failure in the post-meningitic group was a stoma obstruction, and no failure was observed among the 10 myelomeningoceles or in the 2 patients with an undetermined cause.

### 3.6. Mortality

Five deaths were recorded, an overall mortality of 4.2% (1.4 - 9.5), in four boys and one girl aged 3 to 15 months. Deaths occurred between the first and the twentieth postoperative day, with a median of 7 days; the 30-day mortality is therefore also 4.2%. The cases are detailed in **Table 4**.

**Table 4.** The five deaths observed.

| Case | Age       | Day    | Cause of death                                                                    | Attribution to the procedure          |
|------|-----------|--------|-----------------------------------------------------------------------------------|---------------------------------------|
| D1   | 4 months  | Day 1  | Delayed anaesthetic recovery and status epilepticus                               | Indeterminate                         |
| D2   | 3 months  | Day 2  | Isolated status epilepticus                                                       | Indeterminate                         |
| D3   | 15 months | Day 7  | Delayed anaesthetic recovery and status epilepticus                               | Indeterminate                         |
| D4   | 11 months | Day 15 | <i>Staphylococcus aureus</i> meningitis consecutive to a cerebrospinal fluid leak | Attributable (indirect)               |
| D5   | 6 months  | Day 20 | <i>Neisseria meningitidis</i> community-acquired meningitis, neurological sepsis  | Not attributable (community-acquired) |

Four boys and one girl; the individual sex of each case was not available in the records. All had triventricular hydrocephalus from aqueductal stenosis. Median time to death: 7 days; all deaths occurred before the thirtieth postoperative day. Attribution is classified as direct, indirect (attributable), indeterminate (relationship neither established nor excluded from the records) or not attributable (intercurrent community-acquired). No death was directly attributable; procedure-attributable mortality is 0.8% (1 patient, D4); three deaths (D1 - D3) are of indeterminate cause and one (D5) is not attributable.

No death was directly attributable to an intraoperative technical complication. A single death (0.8%; 0.0 - 4.6) was indirectly attributable to the procedure: the *Staphylococcus aureus* meningitis that followed a CSF leak. One death (0.8%; 0.0 - 4.6) was not attributable: the community-acquired *Neisseria meningitidis* meningitis described above. Three further deaths (2.5%; 0.5 - 7.1) were of indeterminate cause—isolated status epilepticus in one and status epilepticus with delayed anaesthetic recovery in the other two—their relationship to the procedure

or to perioperative care being neither established nor excluded from the records. Two deaths were of infectious origin, but only one from a healthcare-associated infection. In a sensitivity analysis treating the community-acquired case (D5) as a healthcare-associated infection, procedure-attributable mortality would be 2 patients (1.7%; 0.2 - 5.9). All five deceased patients had triventricular hydrocephalus from aqueductal stenosis.

### 3.7. Severity of Complications

Clavien-Dindo grading of the 18 events gave 3 grade I events, 1 grade II, no grade IIIa, 9 grade IIIb, no grade IV and 5 grade V (**Table 2**), the five grade-V events being the five deaths. Grades I and II, requiring neither a procedure nor anaesthesia, represented 4 of the 18 events (22.2%); grades IIIb and V, requiring reoperation or resulting in death, 14 of 18 (77.8%), *i.e.*, 13 patients (10.8%).

## 4. Discussion

In this series of 120 infants treated by ETV + CPC, all-cause postoperative morbidity was 14.2% (11.7% of infants having a non-fatal complication), mortality 4.2% and the failure rate 11.7%. Recording the times to onset, analysing the attribution of infections and grading severity take the description beyond a simple count of events.

### 4.1. Overall Morbidity and Severity

Secondary stoma obstruction was both the most frequent complication (5.0%) and the leading identifiable cause of failure. It most often results from cicatricial closure of the ventriculostomy, promoted by inflammatory remodelling and by the arachnoid membranes of the prepontine cisterns; a post-infectious aetiology is scored zero in the endoscopic third ventriculostomy success score because of the risk it carries [10]. Obstruction affected 10.0% of our post-meningitic hydrocephalus cases versus 6.5% of the aqueductal stenoses, in the direction of that scoring but without possible interpretation given the size of the first group; Warf's Ugandan series, moreover, finds no worse outcome for post-infectious forms in infants under one year of age [7]. No obstruction occurred among the 21 Dandy-Walker malformations, whose three failures were all infectious or recurrences without documented obstruction—an observation compatible with Warf *et al.* [15], but on too small a number to go beyond a hint.

The meta-analysis by Albalkhi *et al.*, covering 1918 infants, reports an overall complication rate of 4% after ETV + CPC [11]. Our recorded complication rate of 11.7% is higher, and the Clavien-Dindo grading explains part of the gap: more than a quarter of our events are grade I or II—hyperthermia, strabismus, superficial wound suppuration—which many series do not report. Restricting the count to events that required a procedure under general anaesthesia or that resulted in death yields a severe-morbidity rate of 10.8% (13 patients, Clavien-Dindo IIIb - V). The heterogeneity of definitions and follow-up durations across the included

studies, which the authors note as a limitation, adds to this. Crude comparison between series therefore has little value without a shared definition of complication: the prospective series by Stone and Warf and by the Hydrocephalus Clinical Research Network, conducted under very different monitoring conditions, report profiles that are not superimposable on those of the African series [16] [17].

The absence of any basilar trunk injury deserves to be emphasized, injury to the basilar trunk being the most feared complication of ventriculostomy [18]; the intraoperative bleeding that did occur was minor and controlled by irrigation in every case (Section 3.1). Obtained over 120 procedures, the absence of basilar injury remains compatible with a real risk: the upper bound of the 95% confidence interval of an event not observed in 120 is 3.0%.

#### 4.2. Infectious Complications: Attribution Changes the Reported Rate

The case-by-case analysis of the four cases of meningitis yields what seems to us the most transferable result of this work. The crude rate of postoperative meningitis is 3.3%, but one case—day 18, no leak, no operative site abnormality, *Neisseria meningitidis*—is intercurrent community-acquired meningitis. The study region belongs to the African meningitis belt, and *Neisseria meningitidis* is not a surgical site infection agent; attributing it to the procedure would have inflated the healthcare-associated infection rate by a third, whereas it in fact stands at 2.5%, closer to the 1% reported by Diallo *et al.* in Mali [19] and consistent with other sub-Saharan series [20].

The consequence goes beyond accounting. Where community-acquired meningitis is endemic, an infection rate computed without attribution analysis mechanically overestimates the responsibility of the endoscope reprocessing chain and may lead to poorly targeted corrective measures. African series should report separately the meningitis cases occurring after the procedure and those attributable to care, specifying the time to onset, the organism and the state of the operative site.

The infections truly related to the procedure affected 4 patients (3.3%), only one of whom died, and this death followed a cutaneo-dural breach: prevention of CSF leak, which depends directly on the closure technique, is thus the most direct lever for reducing infectious mortality.

#### 4.3. Timing and Organization of Monitoring

The timing data reveal two risk periods of different natures. Infectious, parietal and neurological complications were concentrated in the first two weeks, and 77.8% of all events occurred before the thirtieth day. Stoma obstructions, conversely, were spread from day 21 to the eighth month: late by nature, they escape any monitoring confined to the perioperative period.

The organizational consequence is direct. Close monitoring during the first thirty days captures most of the acute complications but would miss four of the

six stoma obstructions. Scheduled follow-up at three, six and twelve months, with an emergency consultation as soon as signs of raised intracranial pressure reappear, is necessary to detect them: our last obstruction was diagnosed at the eighth month, in a patient who would not have been reviewed had follow-up stopped at six months.

#### 4.4. Failure, Reoperation and Shunt-Free Survival

The failure rate of 11.7% corresponds to a success rate of 88.3%, higher than the average of 59% reported by Albalkhi *et al.* [11] and than the 47% of Diallo *et al.* [19]. Interpreting this gap belongs to the companion work on preoperative factors; we retain only the practical consequence, namely that a shunt was avoided in a large majority of patients. The Kaplan-Meier estimate is more conservative than the crude rates: 94.8% at six months and 92.7% at twelve months, a plateau to be read with caution since few patients remained under observation beyond the first year.

The three endoscopic revisions performed for stoma obstruction controlled the hydrocephalus without subsequent shunting. This suggests that endoscopic reassessment may be an option in selected patients before considering a definitive shunt; the three cases occurred between day 21 and the fifth month, with no identifiable preferential time window. Confirmation on larger numbers and with longer follow-up is needed.

#### 4.5. Mortality in Perspective

The overall mortality of 4.2% lies within the range of the African series. Diallo *et al.* report 8% mortality at twelve months in 199 Malian infants [19]. Alali *et al.*, in Malawi, find one-year survival of 80% after endoscopic third ventriculostomy with or without choroid plexus cauterization versus 78% after shunting [21]; Chimaliro *et al.*, in the same country, report one-year mortality of 15% after either technique, for event-free survival of 67.2% [22]. These comparisons call for caution: our 4.2% covers deaths all occurring before day 30, in a cohort a quarter of which was not reviewed beyond the first month, whereas the figures cited are one-year mortalities. Our rate must be read as early mortality.

The attribution analysis leads to a nuanced conclusion. No death was directly attributable to an intraoperative technical incident, and only one was indirectly attributable, through an infection consecutive to a CSF leak: mortality attributable to the procedure is therefore 0.8%, not 4.2%. The other four comprised one death following an intercurrent community-acquired meningitis and three deaths of indeterminate cause, their relationship to the procedure being neither established nor excluded retrospectively. This argues against reducing the mortality observed after ETV + CPC to the responsibility of the endoscopic procedure: the initial neurological severity, the chronicity of the hydrocephalus at presentation, the conditions of infant anaesthesia and intercurrent conditions account for the greater part of it [3] [20].

The fact that all five deceased patients had aqueductal stenosis with triventricular hydrocephalus must be interpreted with caution: this aetiology represents 64.2% of the cohort, which mechanically makes it the most exposed group in absolute terms, and it remains one of the best-recognized indications for the procedure [7] [10]. No conclusion about an association between aetiology and mortality can be drawn from five events.

#### 4.6. Implications for Practice

Four practical consequences emerge: the first twenty postoperative days are the critical window for neurological monitoring and for monitoring anaesthetic recovery; prevention of CSF leak warrants particular attention, the only complication that led to a death attributable to the procedure; follow-up must be scheduled up to one year to capture late stoma obstructions; and healthcare-associated infections should be reported separately from intercurrent community-acquired infections so that published rates are comparable between African centres.

Against shunting, ETV + CPC avoids permanent hardware in a substantial proportion of infants, and with it mechanical malfunction, shunt infection and repeated reoperations [5] [6]—an advantage that counts particularly where access to neurosurgical facilities and the availability of valves are constrained [23] [24].

#### 4.7. Strengths and Limitations

The retrospective, single-centre nature exposes the study to information bias, with the quality of the data depending on the completeness of the records. The heterogeneity of follow-up is the main limitation: at least 23.3% of the cohort had no assessment beyond the first postoperative month, and the individual follow-up of the others is not documented. The Kaplan-Meier estimate partly corrects this bias for shunt-free survival, but the crude complication rates remain minimum estimates, in particular for late stoma obstructions. Deaths were treated as censoring in the Kaplan-Meier analysis whereas they constitute a competing event; because all five deaths occurred early, the competing-risk cumulative-incidence analysis (Section 3.4) confirms the Kaplan-Meier estimate to within 0.3%, the cumulative incidence of shunting being 7.0% at twelve months.

The attribution of the meningitis cases was established retrospectively, without criteria predefined at data collection; classifying a case as probable healthcare-associated infection, with no organism isolated, involves a degree of judgement. The Clavien-Dindo grading was likewise applied retrospectively; the five deaths, including the three early neurological or anaesthetic ones, are counted as grade V. The absence of systematic postoperative imaging may have left paucisymptomatic obstructions unrecognized, and the small number of events precludes any search for associated factors. Finally, the absence of a shunted control group allows no direct comparison; the study received retrospective institutional ethics approval, with no constituted committee having been available to review the protocol pro-

spectively during the study period.

## 5. Conclusion

In this cohort of 120 infants, ETV + CPC was accompanied by an all-cause post-operative morbidity of 14.2%—non-fatal complications affecting 11.7% of infants—and a mortality of 4.2%, but mortality attributable to the procedure was 0.8%, a single death resulting from an infection consecutive to a CSF leak. One of the four cases of meningitis was an intercurrent community-acquired infection, which brings the healthcare-associated infection rate from 3.3% down to 2.5% and underlines the need for attribution analysis where meningococcal disease is endemic. The chronology of events separates an acute phase concentrated in the first month from stoma obstructions that spread out to the eighth month, which justifies close initial monitoring prolonged by scheduled follow-up up to one year. Shunt-free survival was 92.7% at twelve months. Prospective multicentre studies, with explicit case definitions and standardized follow-up, remain necessary in sub-Saharan Africa.

## Consent for Publication

Not applicable: the manuscript contains no individual data allowing a patient to be identified.

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## Data Availability

The anonymized individual data are available from the corresponding author on reasonable request and subject to institutional approval.

## Author Contributions

F.S.L.T. conceived and designed the study, performed the procedures, collected and analysed the data and drafted the manuscript. K.Y.S.D., Y.B.F., K.J.-B.K. and K.L.A.D. contributed to data collection and to the interpretation of the results. A.H. supervised the study and critically revised the manuscript for important intellectual content. All authors read and approved the final version of the manuscript.

## Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

## References

- [1] Dewan, M.C., Rattani, A., Mekary, R., Glancz, L.J., Yunusa, I., Baticulon, R.E., *et al.*

- (2019) Global Hydrocephalus Epidemiology and Incidence: Systematic Review and Meta-Analysis. *Journal of Neurosurgery*, **130**, 1065-1079. <https://doi.org/10.3171/2017.10.jns17439>
- [2] Aukrust, C.G., Paulsen, A.H., Uche, E.O., Kamalo, P.D., Sandven, I., Fjeld, H.E., *et al.* (2022) Aetiology and Diagnostics of Paediatric Hydrocephalus across Africa: A Systematic Review and Meta-Analysis. *The Lancet Global Health*, **10**, e1793-e1806. [https://doi.org/10.1016/s2214-109x\(22\)00430-2](https://doi.org/10.1016/s2214-109x(22)00430-2)
- [3] Darko, K., Guirguis, M., Kakulamari, S., Farid, M., Venkatesh, P., Osei Adjei, E.K., *et al.* (2024) Presentation, Management, and Outcomes of Pediatric Hydrocephalus in Africa: A Systematic Review and Meta-Analysis of 12,355 Patients. *Journal of Neurosurgery: Pediatrics*, **34**, 315-327. <https://doi.org/10.3171/2024.5.peds23595>
- [4] Kahle, K.T., Kulkarni, A.V., Limbrick, D.D. and Warf, B.C. (2016) Hydrocephalus in Children. *The Lancet*, **387**, 788-799. [https://doi.org/10.1016/s0140-6736\(15\)60694-8](https://doi.org/10.1016/s0140-6736(15)60694-8)
- [5] Gathura, E., Poenaru, D., Bransford, R. and Albright, A.L. (2010) Outcomes of Ventriculoperitoneal Shunt Insertion in Sub-Saharan Africa. *Journal of Neurosurgery: Pediatrics*, **6**, 329-335. <https://doi.org/10.3171/2010.7.peds09543>
- [6] Mbabazi-Kabachelor, E., Shah, M., Vaughan, K.A., Mugamba, J., Ssenyonga, P., Onen, J., *et al.* (2019) Infection Risk for Bactiseal Universal Shunts versus Chhabra Shunts in Ugandan Infants: A Randomized Controlled Trial. *Journal of Neurosurgery: Pediatrics*, **23**, 397-406. <https://doi.org/10.3171/2018.10.peds18354>
- [7] Warf, B.C. (2005) Comparison of Endoscopic Third Ventriculostomy Alone and Combined with Choroid Plexus Cauterization in Infants Younger than 1 Year of Age: A Prospective Study in 550 African Children. *Journal of Neurosurgery: Pediatrics*, **103**, 475-481. <https://doi.org/10.3171/ped.2005.103.6.0475>
- [8] Warf, B.C. (2013) The Impact of Combined Endoscopic Third Ventriculostomy and Choroid Plexus Cauterization on the Management of Pediatric Hydrocephalus in Developing Countries. *World Neurosurgery*, **79**, S23.e13-S23.e15. <https://doi.org/10.1016/j.wneu.2011.02.012>
- [9] Warf, B.C. and Campbell, J.W. (2008) Combined Endoscopic Third Ventriculostomy and Choroid Plexus Cauterization as Primary Treatment of Hydrocephalus for Infants with Myelomeningocele: Long-Term Results of a Prospective Intent-to-Treat Study in 115 East African Infants. *Journal of Neurosurgery: Pediatrics*, **2**, 310-316. <https://doi.org/10.3171/ped.2008.2.11.310>
- [10] Warf, B.C., Mugamba, J. and Kulkarni, A.V. (2010) Endoscopic Third Ventriculostomy in the Treatment of Childhood Hydrocephalus in Uganda: Report of a Scoring System That Predicts Success. *Journal of Neurosurgery: Pediatrics*, **5**, 143-148. <https://doi.org/10.3171/2009.9.PEDS09196>
- [11] Albalkhi, I., Garatli, S., Helal, B., Saleh, T., AlRamadan, A.H. and Warf, B.C. (2023) Morbidity and Etiology-Based Success Rate of Combined Endoscopic Ventriculostomy and Choroid Plexus Cauterization: A Systematic Review and Meta-Analysis of 1918 Infants. *Neurosurgical Review*, **46**, Article No. 180. <https://doi.org/10.1007/s10143-023-02091-4>
- [12] von Elm, E., Altman, D.G., Egger, M., Pocock, S.J., Gøtzsche, P.C. and Vandenbroucke, J.P. (2007) The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) Statement: Guidelines for Reporting Observational Studies. *The Lancet*, **370**, 1453-1457. [https://doi.org/10.1016/s0140-6736\(07\)61602-x](https://doi.org/10.1016/s0140-6736(07)61602-x)
- [13] Dindo, D., Demartines, N. and Clavien, P. (2004) Classification of Surgical Complications: A New Proposal with Evaluation in a Cohort of 6336 Patients and Results of a Survey. *Annals of Surgery*, **240**, 205-213.

- <https://doi.org/10.1097/01.sla.0000133083.54934.ae>
- [14] Kaplan, E.L. and Meier, P. (1958) Nonparametric Estimation from Incomplete Observations. *Journal of the American Statistical Association*, **53**, 457-481. <https://doi.org/10.1080/01621459.1958.10501452>
  - [15] Warf, B.C., Dewan, M. and Mugamba, J. (2011) Management of Dandy-Walker Complex-Associated Infant Hydrocephalus by Combined Endoscopic Third Ventriculostomy and Choroid Plexus Cauterization. *Journal of Neurosurgery: Pediatrics*, **8**, 377-383. <https://doi.org/10.3171/2011.7.peds1198>
  - [16] Kulkarni, A.V., Riva-Cambrin, J., Rozzelle, C.J., Naftel, R.P., Alvey, J.S., Reeder, R.W., *et al.* (2018) Endoscopic Third Ventriculostomy and Choroid Plexus Cauterization in Infant Hydrocephalus: A Prospective Study by the Hydrocephalus Clinical Research Network. *Journal of Neurosurgery: Pediatrics*, **21**, 214-223. <https://doi.org/10.3171/2017.8.peds17217>
  - [17] Stone, S.S.D. and Warf, B.C. (2014) Combined Endoscopic Third Ventriculostomy and Choroid Plexus Cauterization as Primary Treatment for Infant Hydrocephalus: A Prospective North American Series. *Journal of Neurosurgery: Pediatrics*, **14**, 439-446. <https://doi.org/10.3171/2014.7.peds14152>
  - [18] Bouras, T. and Sgouros, S. (2011) Complications of Endoscopic Third Ventriculostomy. *Journal of Neurosurgery: Pediatrics*, **7**, 643-649. <https://doi.org/10.3171/2011.4.peds10503>
  - [19] Diallo, O., Dama, M., Konan, L., Coulibaly, O., Sissoko, D. and Maiga, A.H. (2023) Endoscopic Third Ventriculostomy with Choroid Plexus Cauterization in Infantile Hydrocephalus: An Experience from Mali. *Pediatric Neurosurgery*, **58**, 38-44. <https://doi.org/10.1159/000529453>
  - [20] Santos, M.M., Rubagumya, D.K., Dominic, I., Brighton, A., Colombe, S., O'Donnell, P., *et al.* (2017) Infant Hydrocephalus in Sub-Saharan Africa: The Reality on the Tanzanian Side of the Lake. *Journal of Neurosurgery: Pediatrics*, **20**, 423-431. <https://doi.org/10.3171/2017.5.peds1755>
  - [21] Alali, A., Alkabouni, W., Aretz, V., Volpert, T., Makanjira, Y., Kampeni, M., *et al.* (2025) One Year Mortality after Pediatric Hydrocephalus Treatment: A Comparative Analysis of Endoscopic Third Ventriculostomy and Ventriculoperitoneal Shunt. *Frontiers in Surgery*, **12**, Article 1538899. <https://doi.org/10.3389/fsurg.2025.1538899>
  - [22] Chimaliro, S., Hara, C. and Kamalo, P. (2022) Mortality and Complications 1 Year after Treatment of Hydrocephalus with Endoscopic Third Ventriculostomy and Ventriculoperitoneal Shunt in Children at Queen Elizabeth Central Hospital, Malawi. *Acta Neurochirurgica*, **165**, 61-69. <https://doi.org/10.1007/s00701-022-05392-7>
  - [23] Kantawala, B., Khattab, M., Elawad, S.O., Assker, M., Cherri, B., Nazir, A., *et al.* (2023) Addressing Hydrocephalus in Africa: Challenges and Way Forward. *Health Science Reports*, **6**, e1759. <https://doi.org/10.1002/hsr2.1759>
  - [24] Kulkarni, A.V., Schiff, S.J., Mbabazi-Kabachelor, E., Mugamba, J., Ssenyonga, P., Donnelly, R., *et al.* (2017) Endoscopic Treatment versus Shunting for Infant Hydrocephalus in Uganda. *New England Journal of Medicine*, **377**, 2456-2464. <https://doi.org/10.1056/nejmoa1707568>

### **List of Abbreviations**

CI: confidence interval;

CPC: choroid plexus cauterization;

CSF: cerebrospinal fluid;

CT: computed tomography;

ETV: endoscopic third ventriculostomy;

HAI: healthcare-associated infection;

MRI: magnetic resonance imaging;

STROBE: Strengthening the Reporting of Observational Studies in Epidemiology.

# Supplementary Material

**Table S1.** Delineation of the five manuscripts drawn from the same 120-infant cohort.

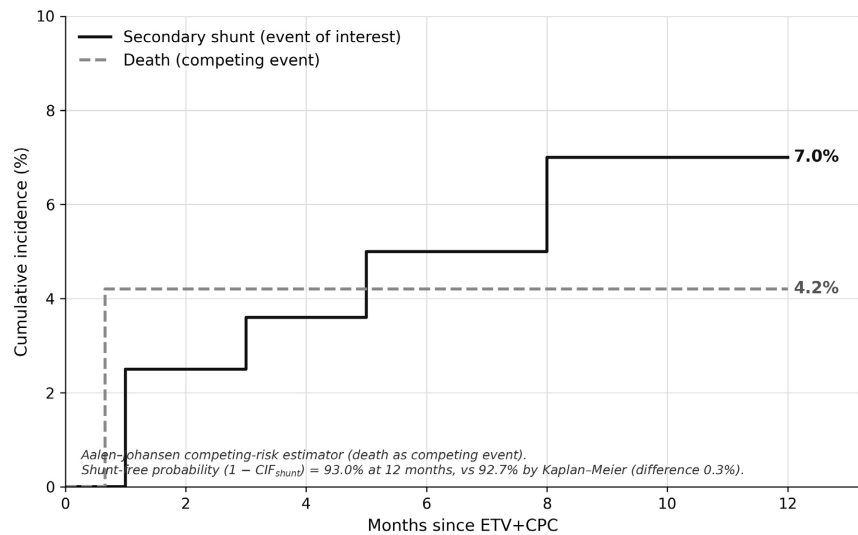
| Manuscript                                  | Primary question/focus                                                                  | Unique endpoints and variables                                                                                                                                        | Relationship to present work                        |
|---------------------------------------------|-----------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------|
| <b>Present manuscript</b>                   | Nature, timing, severity and attribution of complications; failure; survival; mortality | Clavien-Dindo grading; all-cause vs attributable adverse events; meningitis attribution; shunt-free survival (Kaplan-Meier and competing-risk); mortality attribution | — (this study)                                      |
| <b>1. Preoperative profile</b>              | Cohort at presentation                                                                  | Age, sex, aetiology, head circumference, clinical signs, baseline imaging                                                                                             | Shares only baseline descriptors ( <b>Table 1</b> ) |
| <b>2. Clinical outcomes &amp; economics</b> | ETV + CPC versus shunting                                                               | Success rate; direct and indirect costs; cost-effectiveness                                                                                                           | Comparative and economic endpoints only             |
| <b>3. Predictors of success</b>             | Preoperative predictors of success                                                      | ETV Success Score; multivariable model of success                                                                                                                     | Success endpoint; no attribution or timing          |
| <b>4. Neuroendoscopy programme</b>          | Establishing the programme                                                              | Training, learning curve, equipment, sustainability                                                                                                                   | Programme-level, non-outcome content                |

The five analyses share the same patients, period (1 January 2024-30 April 2026) and inclusion criteria; each addresses a distinct question, and the present manuscript reproduces no primary result of the others. Overlap is limited to the shared baseline description (**Table 1**). No effectiveness, cost, predictor-of-success or programme-development result appears in the present manuscript.

**Table S2.** Shunt-free survival: Kaplan-Meier versus competing-risk cumulative incidence.

| Time      | CIF shunt (%) | CIF death (%) | Shunt-free, competing-risk (%) | Shunt-free, Kaplan-Meier (%) | Event-free (%) |
|-----------|---------------|---------------|--------------------------------|------------------------------|----------------|
| 1 month   | 2.5           | 4.2           | 97.5                           | 97.4                         | 93.3           |
| 3 months  | 3.6           | 4.2           | 96.4                           | 96.2                         | 92.2           |
| 6 months  | 5.0           | 4.2           | 95.0                           | 94.8                         | 90.9           |
| 12 months | 7.0           | 4.2           | 93.0                           | 92.7                         | 88.8           |

CIF: cumulative incidence function (Aalen-Johansen estimator; death competing with secondary shunting). Shunt-free (competing-risk) = 1 – CIF shunt; event-free (alive and free of a shunt) = 1 – CIF shunt – CIF death. The competing-risk and Kaplan-Meier shunt-free estimates differ by at most 0.3%. Computed in Python 3.12 (NumPy 2.4, SciPy 1.17).



New analysis in response to Reviewer 2. Aalen-Johansen estimator, death as competing event. Cumulative incidence of shunting 2.5/3.6/5.0/7.0% at 1/3/6/12 months (shunt-free 93.0% at 12 months), materially unchanged from Kaplan-Meier (92.7%); all five deaths occurred by day 20. Computed in Python 3.12 (NumPy, SciPy).

**Figure S1.** Cumulative incidence of secondary shunting and of death after ETV + CPC (competing-risk analysis).