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Efficacy and Safety of Endoscopic Third Ventriculostomy Compared with Ventriculoperitoneal Shunting in Pediatric Post-Inflammatory Hydrocephalus: A Systematic Review and Meta-Analysis

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Abstract

Background: Ventriculoperitoneal shunting (VPS) remains the standard treatment for pediatric post-inflammatory hydrocephalus because it provides reliable cerebrospinal fluid diversion, but it is associated with infection, treatment failure, repeated revisions, and lifelong device dependency. Endoscopic third ventriculostomy (ETV) offers a shunt-independent alternative that may reduce long-term device-related complications, although its comparative efficacy and safety remain uncertain.

Methods: Nine databases were searched from inception to 28 February 2026 under a registered PROSPERO protocol (CRD420261382819). Random-effects models were used for direct comparative meta-analyses, with supplementary single-arm syntheses to estimate pooled procedure-specific event rates.

Results: Of 3,995 records identified and 2,092 screened after deduplication, 22 studies comprising 13,778 children were included. In comparative analyses, ETV and VPS showed no statistically

significant difference in treatment success (RR 0.98, 95% CI 0.73–1.31), mortality (RR 1.24, 95% CI 0.68–2.28), or overall complications (RR 2.09, 95% CI 0.17–25.27). In single-arm analyses, the pooled success rate was 51% for ETV and 63% for VPS. The pooled mortality rate was 7% for ETV and 4% for VPS. Revision rates were 45% and 39%, respectively, while overall complication rates were 25% for ETV and 26% for VPS. Infection rates were 8% for ETV and 13% for VPS.

Conclusions: Current evidence does not show a clear superiority of ETV or VPS for pediatric post-inflammatory hydrocephalus. ETV may show numerically lower infection and mortality, but this should be interpreted cautiously given marked heterogeneity and limited head-to-head data.

Keywords: Endoscopic Third Ventriculostomy, Ventriculoperitoneal shunt, Post-Inflammatory Hydrocephalus, Efficacy, Safety

Introduction

Hydrocephalus is defined as an accumulation of cerebrospinal fluid (CSF) inside the cerebral ventricles due to an abnormal state of production, flow, or absorption, resulting in ventricular dilatation and increased intracranial pressure (ICP) [37]. Hydrocephalus can be divided into two categories based on different pathophysiologies: communicating and non-communicating. The cause of communicating hydrocephalus involves impaired absorption of CSF, such as post-hemorrhagic or post-infectious changes [16].

Although both arise from different initiating events, infection and intraventricular hemorrhage, respectively, increasing evidence suggests that they share important inflammatory mechanisms. In infection, pathogen-associated molecular patterns (PAMPs) activate innate immune receptors, particularly Toll-like receptors (TLRs), whereas blood and its degradation products in hemorrhage act as damage-associated molecular patterns (DAMPs) that activate similar inflammatory pathways. Activation of these pathways, including TLR4–NF-κB signaling, promotes the release of pro-inflammatory cytokines such as tumor necrosis factor-α, interleukin-1β, and interleukin-6, as well as the recruitment and activation of immune cells within the cerebrospinal fluid spaces. Sustained neuroinflammation may impair cerebrospinal fluid homeostasis through choroid plexus hypersecretion, ependymal injury, and scarring of intraventricular or subarachnoid CSF pathways. Therefore, both post-infectious and post-hemorrhagic hydrocephalus may be considered overlapping forms of "inflammatory hydrocephalus," despite their distinct initial causes [30].

The treatment for pediatric post-inflammatory hydrocephalus is commonly done by performing a CSF diversion using a ventriculoperitoneal shunt (VPS). However, this procedure is associated with several complications, such as infection and obstruction, which may require revision surgery and can result in long-term dependence on an implanted CSF-diversion device [1]. In recent years, endoscopic third ventriculostomy (ETV) has been offered as an alternative that may reduce long-term device-related complications [11]. Thus, we conducted a systematic review and meta-analysis comparing the efficacy and safety of these methods, evaluating success rate, complications, revision rate, and mortality in pediatric post-inflammatory hydrocephalus.

Methods

This systematic review and meta-analysis followed the recommendations of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement [24]. This systematic review and meta-analysis was registered to the International Prospective Register of Systematic Reviews (PROSPERO) under the registration number CRD420261382819.

Search Strategy and Data Extraction

A systematic search was performed in nine databases from inception to 28 February 2026. The following electronic databases were searched: Scopus, ScienceDirect, SpringerLink, PubMed, Sage, Cochrane, Web of Science, Taylor and Francis, and EBSCO. The search strategy used combinations of keywords and Boolean operators related to cerebrospinal fluid diversion procedures and secondary hydrocephalus etiologies, including ("endoscopic third ventriculostomy" OR "ETV" OR "VP shunt" OR "Ventriculoperitoneal Shunt") AND ("post-infectious hydrocephalus" OR "post-hemorrhagic hydrocephalus" OR "PIH" OR "PHH").

Selection Criteria and Endpoints

The eligibility criteria for inclusion of the studies were the following: 1) infants (<2 years) with post-inflammatory hydrocephalus, including post-hemorrhagic or post-infectious; 2) who received ETV or VPS; and 3) studies reporting the outcome of interest. We excluded studies characterized by 1) non-English language or unavailability of full text, 2) not communicating hydrocephalus, and 3) no outcome of interest. The outcomes included were 1) success rate, 2) complications, 3) revision rate, and 4) mortality.

Data Analysis

All statistical analyses were conducted using R (version 4.6.0; R Foundation for Statistical Computing, Vienna, Austria). Results were presented as the risk ratio (RR) with a 95% confidence interval (CI). Heterogeneity was assessed by I^2 the test metric. Random-effects models were prespecified given the anticipated clinical and methodological heterogeneity across studies [14].

Quality Assessment

The methodological quality of the included studies was assessed in accordance with the recommendations of the Cochrane Handbook for Systematic Reviews of Interventions. Randomized controlled trials (RCTs) were evaluated using the revised Cochrane Risk of Bias tool for randomized trials (RoB 2), which assesses bias across five domains: (1) bias arising from the randomization process, (2) bias due to deviations from intended interventions, (3) bias due to missing outcome data, (4) bias in the measurement of the outcome, and (5) bias in the selection of the reported result. Non-randomized studies were assessed using the Risk Of Bias In Non-randomized Studies of Interventions (ROBINS-I V2) tool, which evaluates seven domains: (1) bias due to confounding, (2) bias in the selection of participants, (3) bias in the classification of

interventions, (4) bias due to deviations from intended interventions, (5) bias due to missing data, (6) bias in the measurement of outcomes, and (7) bias in the selection of the reported result. Each study was independently assessed by two reviewers, with disagreements resolved through discussion or consultation with a third reviewer until consensus was reached. As this study analyzed previously published, de-identified aggregate data, and did not involve direct interaction with human participants or animal subjects, no new ethics approval or informed consent was required.

Results

Study Selection and Characteristics

The systematic literature search identified a total of 3,995 records from nine electronic databases, including Scopus (n = 750), ScienceDirect (n = 426), SpringerLink (n = 536), PubMed (n = 661), Sage (n = 470), Cochrane Library (n = 56), Web of Science (n = 680), EBSCO (n = 95), and Taylor & Francis (n = 321). After removing 635 duplicate records and 1,268 records deemed ineligible through automated screening tools, 2,092 records remained for title and abstract screening. About 2,030 records were excluded in the screening process. Consequently, 62 full-text articles were sought for retrieval, of which 8 could not be obtained. The remaining 54 full-text articles were assessed for eligibility. A total of 32 studies were excluded for wrong population (n = 28), wrong intervention (n = 2), and wrong outcomes (n = 2). A total of 22 studies fulfilled all inclusion criteria and were included in the systematic review and quantitative synthesis. The detailed study selection process is presented in the PRISMA 2020 flow diagram (**Fig. 1)**. The characteristics of the 22 included studies are summarized in **Table 1**.

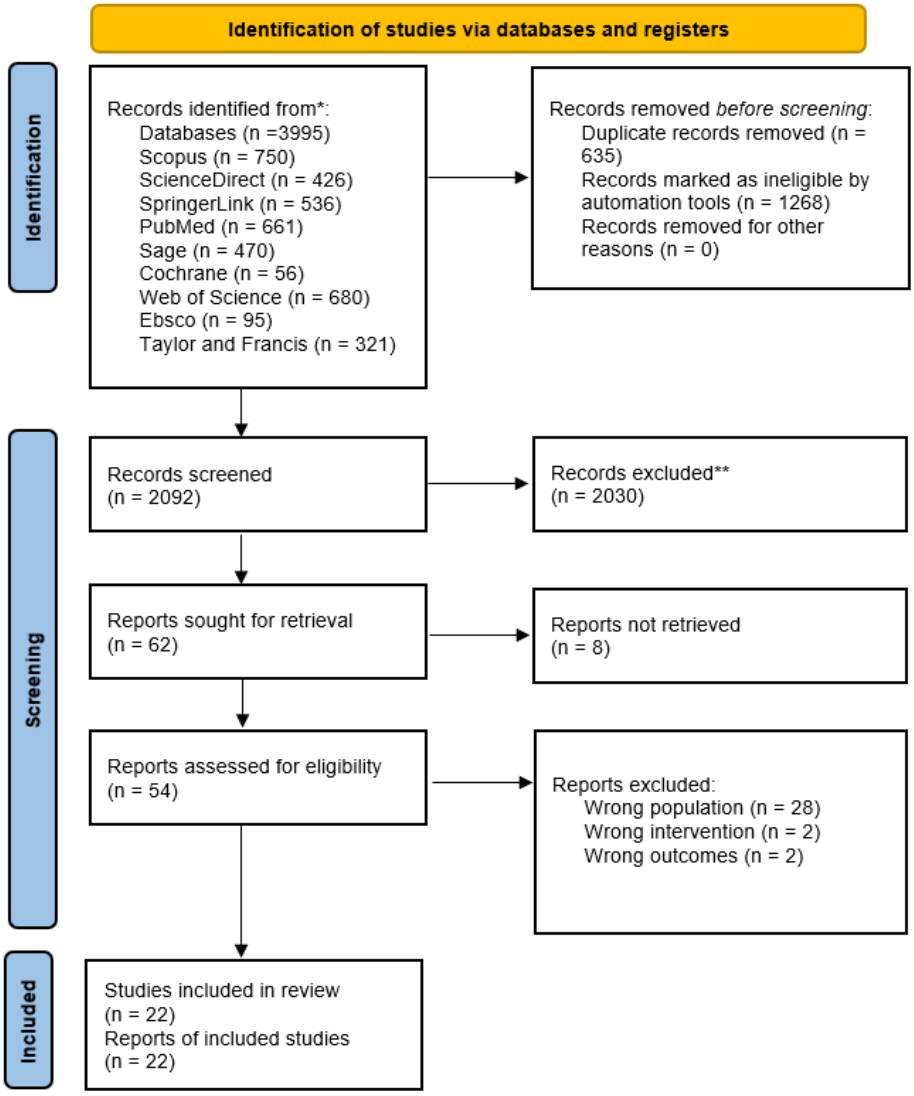


Fig. 1 PRISMA 2020 flow diagram summarizing the literature search and study selection process

Table 1 Study Characteristics

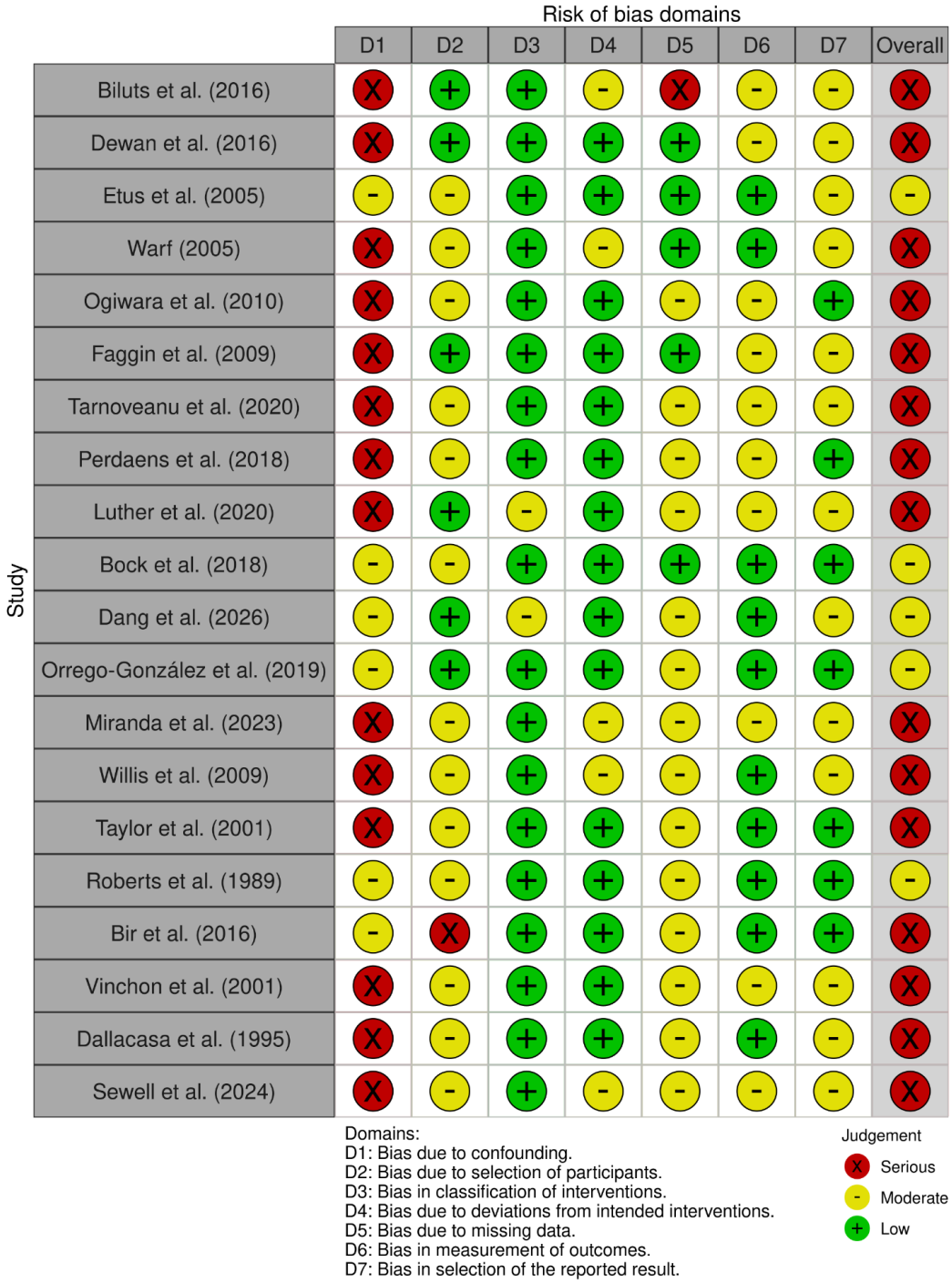
Author, years	Study Design	Location	Population	Age (months)	Intervention	Follow-up (months)	Outcomes
Biluts, 2016 [12]	Retrospective Cohort	Ethiopia, Africa	ETV: 122	11.22 (15.02)	ETV	7.2	Success Rate, Mortality Rate, Complication Rate
Dewan, 2016 [8]	Retrospective Cohort	USA, America	ETV: 57	3.9 (5.3)	ETV	6	Success Rate
Etus, 2005	Retrospective	Turkey,	ETV: 7	NA	ETV	20	Success Rate

[9]	Cohort	Asia					
Warf, 2005 [38]	Retrospective Cohort	Uganda, Africa	ETV: 550	NA	ETV	19	Success Rate, Mortality Rate
Ogiwara, 2010 [22]	Retrospective Cohort	Texas, America	ETV: 8	2.92 (1.32)	ETV	57.4	Success Rate, Revision Rate, Complication Rate
Faggin, 2009 [10]	Retrospective Cohort	Italy, Europe	ETV: 7	NA	ETV	NA	Success Rate
Tarnoveanu, 2020 [34]	Retrospective Cohort	Romania, Europe	ETV: 46	20 (NA)	ETV	12	Success Rate, Revision Rate, Mortality Rate
PerdaensGuus, 2018 [27]	Retrospective Cohort	Belgium, Europe	ETV: 40, VPS: 99	NA	ETV and VPS	58	Success Rate, Revision Rate, Mortality Rate, Complication Rate
Punchak, 2019 [28]	Randomized Control Trial	Uganda, Africa	ETV: 51, VPS: 49	NA	ETV and VPS	24	Success Rate, Mortality Rate
Luther, 2020 [18]	Retrospective Cohort	USA, America	ETV: 4810, VPS: 6206	NA	ETV and VPS	NA	Success Rate, Mortality Rate
Mbabazi-Kabachelor, 2025 [19]	Randomized Control Trial	Uganda, Africa	ETV: 43, VPS: 57	NA	ETV and VPS	60	Success Rate, Mortality Rate, Complication Rate
Bock, 2018 [4]	Retrospective Cohort	Germany, Europe	VPS: 95	NA	VPS	NA	Revision Rate, Complication Rate
Dang, 2026 [6]	Retrospective Cohort	Vietnam, Asia	VPS: 334	NA	VPS	26	Success Rate, Revision Rate, Complication Rate

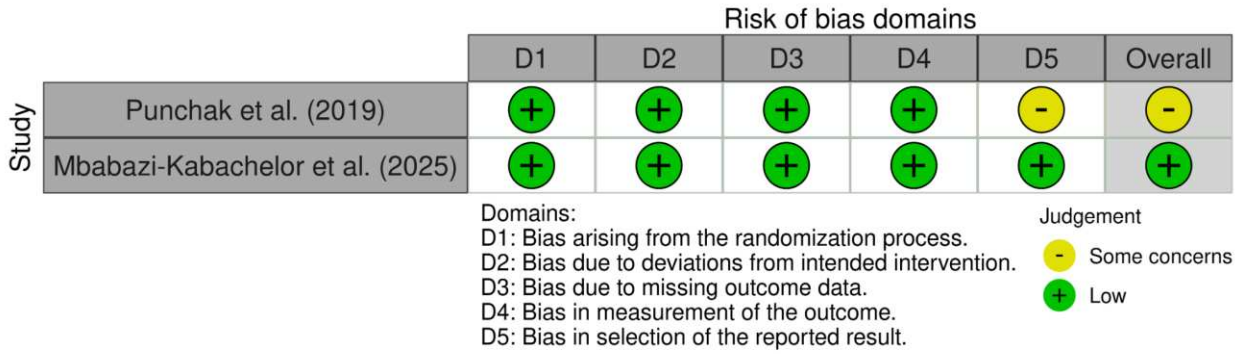
Orrego-González, 2019 [23]	Retrospective Cohort	USA, America	VPS: 83	1.6 (3.4)	VPS	6	Success Rate
Miranda, 2023 [21]	Retrospective Cohort	Spain, Europe	VPS: 133	1.91 (0.28)	VPS	106.38	Complication Rate
Willis, 2009 [39]	Retrospective Cohort	USA, America	VPS: 17	NA	VPS	37.3	Revision Rate, Mortality Rate, Complication Rate
Taylor, 2001 [35]	Retrospective Cohort	South Africa, Africa	VPS: 36	1.3 (0.89)	VPS	60	Revision Rate, Mortality Rate, Complication Rate
Roberts, 1989 [31]	Retrospective Cohort	United Kingdom, Europe	VPS: 14	2 (NA)	VPS	26	Mortality Rate, Complication Rate
Bir, 2016 [3]	Retrospective Cohort	USA, America	VPS: 122	NA	VPS	78	Revision Rate, Complication Rate
Vinchon, 2001 [36]	Retrospective Cohort	France, Europe	VPS: 40	1.25 (NA)	VPS	109	Revision Rate, Mortality Rate, Complication Rate
Dallacasa, 1995 [7]	Retrospective Cohort	Italy, Europe	VPS: 16	NA	VPS	66	Success Rate
Sewell, 2024 [32]	Retrospective Cohort	North America	VPS: 710	NA	VPS	NA	Mortality Rate, Complication Rate

The risk of bias assessment of the included retrospective cohort studies using the ROBINS-I V2 tool revealed an overall moderate-to-serious risk of bias across the included studies (**Fig. 2A**). Bias due to confounding represented the most common source of concern, with the majority of studies judged at serious risk because of inadequate adjustment for baseline differences and the observational nature of the study designs. Overall, 15 of the 20 studies were judged to have a serious overall risk of bias, while the remaining five studies were classified as having a moderate overall risk of bias. No study was considered to be at low overall risk of bias. In contrast,

assessment of the RCTs using the RoB 2 tool demonstrated a substantially lower risk of bias (**Fig. 2B**).



a



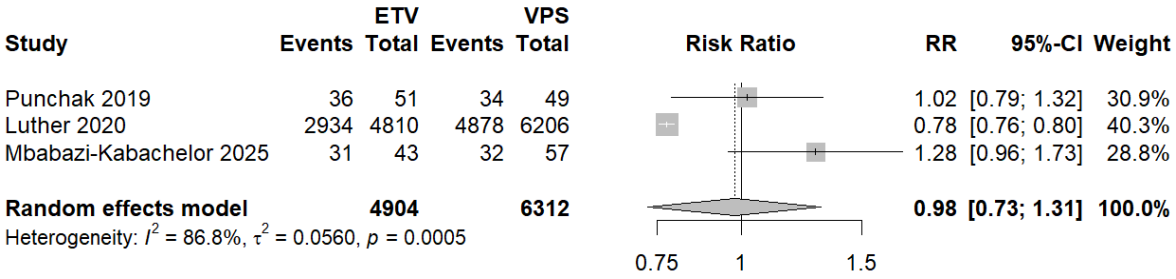
b

Fig. 2 Risk of bias assessment of included studies using (a) ROBINS-I and (b) RoB 2

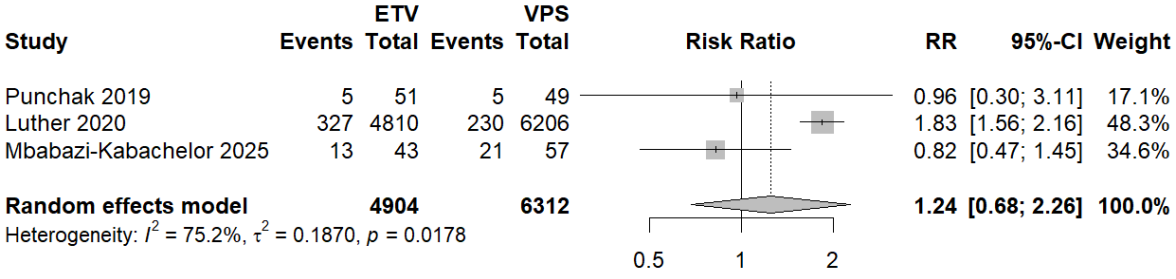
Comparative Meta-Analysis (ETV vs VPS)

The comparative meta-analysis of ETV and VPS for success rate, mortality rate, and total complications is presented in **Fig. 3**.

a.



b.



c.

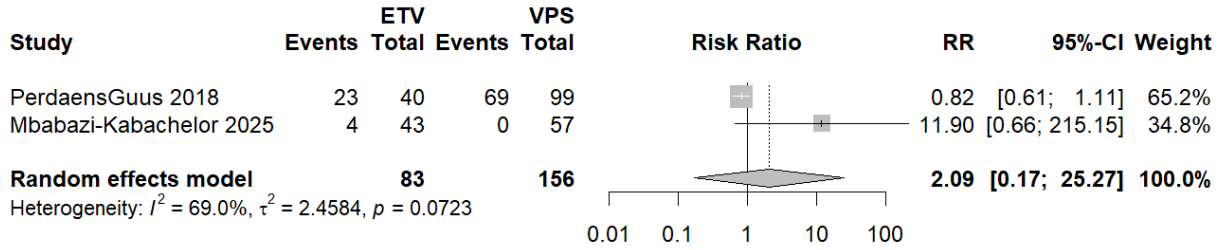


Fig. 3 Forest plots comparing endoscopic third ventriculostomy (ETV) and ventriculoperitoneal shunting (VPS) for (**a**) treatment success, (**b**) mortality, and (**c**) complications

Table 2 Double-Arm Meta-Analysis Summary of ETV versus VPS

Outcome	Studies (n ETV / n VPS)	RR (Random Effects)	95% CI	I^2
Success Rate	3 (4,904 / 6,312)	0.98	0.73 – 1.31	86.8%
Mortality Rate	3 (4,904 / 6,312)	1.24	0.68 – 2.26	75.2%
Total Complication	2 (83 / 156)	2.09	0.17 – 25.27	69.0%

Treatment Success

Three comparative studies involving 4,904 ETV-treated patients and 6,312 VPS-treated patients were included. The pooled analysis demonstrated no significant difference in treatment success between ETV and VPS (RR 0.98, 95% CI 0.73–1.31; I^2 = 86.8%) (**Table 2**). Although individual studies reported varying results, the overall estimate suggested comparable efficacy between the two procedures.

Mortality

Mortality outcomes were available from the same three studies. The pooled mortality risk did not differ significantly between ETV and VPS (RR 1.24, 95% CI 0.68–2.26; I^2 = 75.2%), indicating similar survival outcomes following both interventions.

Total Complications

Two studies reported overall complication rates. No significant difference was observed between treatment groups (RR 2.09, 95% CI 0.17–25.27; I^2 = 69.0%). However, the wide confidence interval indicates substantial uncertainty in the pooled estimate.

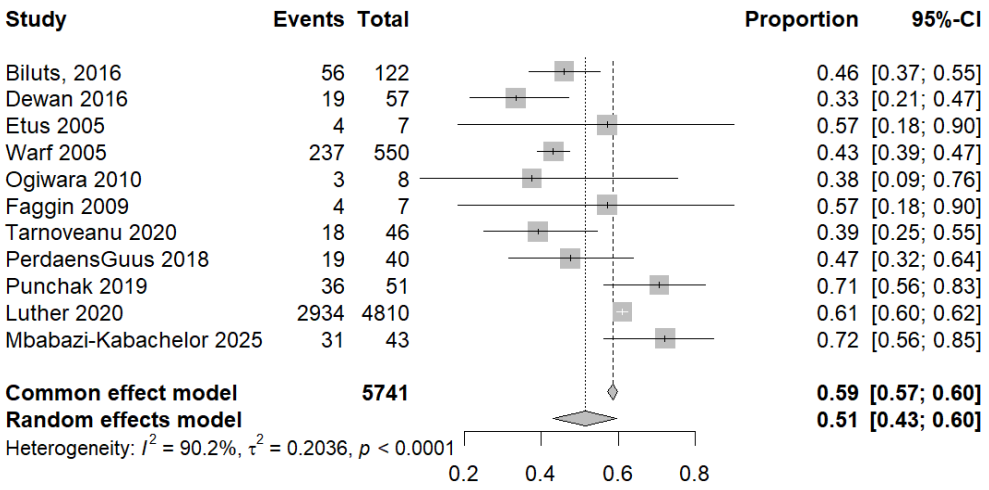
Overall Interpretation

Collectively, comparative analyses demonstrated that ETV and VPS achieved similar rates of treatment success, mortality, and complications, with no statistically significant differences observed across any measured outcomes.

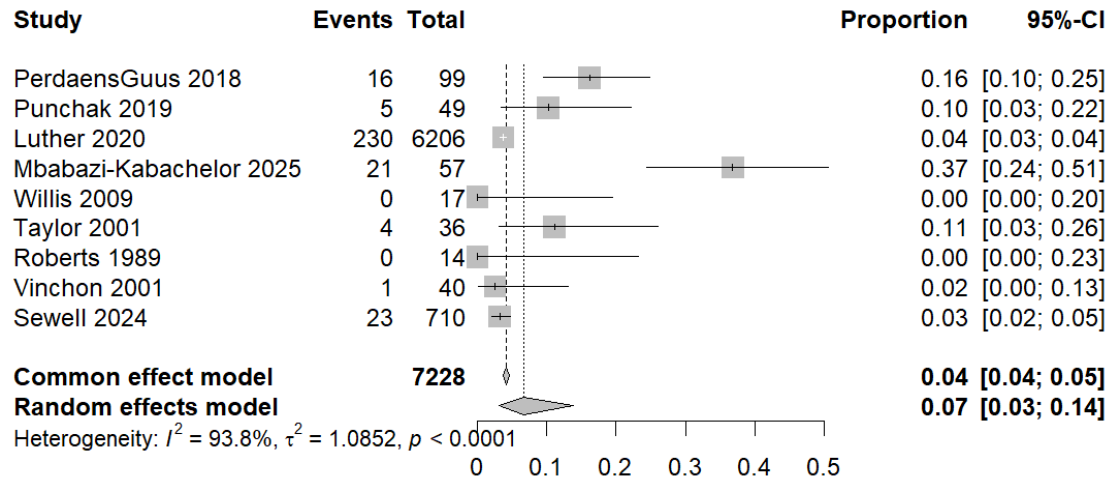
Single-Arm Meta-Analysis

The pooled event rates following ETV, including success rate, mortality rate, revision rate, total complications, infection, and other complications, are presented in **Fig. 4** and summarized in **Table 3**.

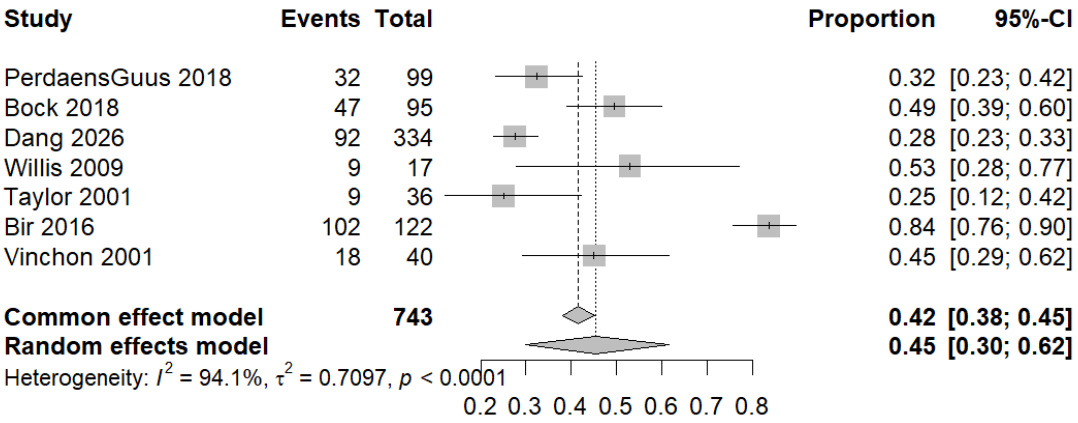
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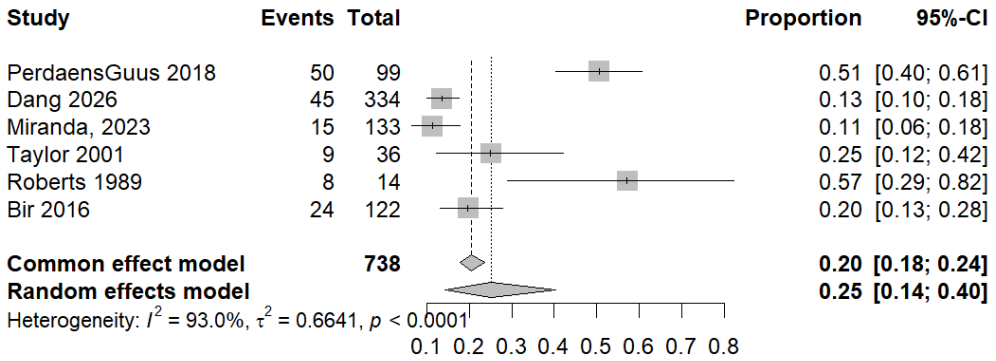
b.



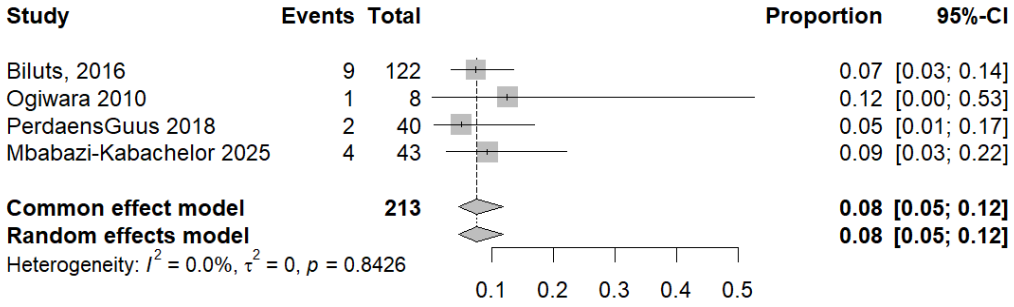
c.


Study Events Total Proportion 95%-CI
PerdaensGuus 2018 32 99 0.32 [0.23; 0.42]
Bock 2018 47 95 0.49 [0.39; 0.60]
Dang 2026 92 334 0.28 [0.23; 0.33]
Willis 2009 9 17 0.53 [0.28; 0.77]
Taylor 2001 9 36 0.25 [0.12; 0.42]
Bir 2016 102 122 0.84 [0.76; 0.90]
Vinchon 2001 18 40 0.45 [0.29; 0.62]
Common effect model 743 0.42 [0.38; 0.45]
Random effects model 0.45 [0.30; 0.62]
Heterogeneity: I^2 = 94.1%, τ^2 = 0.7097, p < 0.0001
0.2 0.3 0.4 0.5 0.6 0.7 0.8

d.


Study Events Total Proportion 95%-CI
PerdaensGuus 2018 50 99 0.51 [0.40; 0.61]
Dang 2026 45 334 0.13 [0.10; 0.18]
Miranda, 2023 15 133 0.11 [0.06; 0.18]
Taylor 2001 9 36 0.25 [0.12; 0.42]
Roberts 1989 8 14 0.57 [0.29; 0.82]
Bir 2016 24 122 0.20 [0.13; 0.28]
Common effect model 738 0.20 [0.18; 0.24]
Random effects model 0.25 [0.14; 0.40]
Heterogeneity: I^2 = 93.0%, τ^2 = 0.6641, p < 0.0001
0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8

e.


Study Events Total Proportion 95%-CI
Biluts, 2016 9 122 0.07 [0.03; 0.14]
Ogiwara 2010 1 8 0.12 [0.00; 0.53]
PerdaensGuus 2018 2 40 0.05 [0.01; 0.17]
Mbabazi-Kabachelor 2025 4 43 0.09 [0.03; 0.22]
Common effect model 213 0.08 [0.05; 0.12]
Random effects model 0.08 [0.05; 0.12]
Heterogeneity: I^2 = 0.0%, τ^2 = 0, p = 0.8426
0.1 0.2 0.3 0.4 0.5

f.

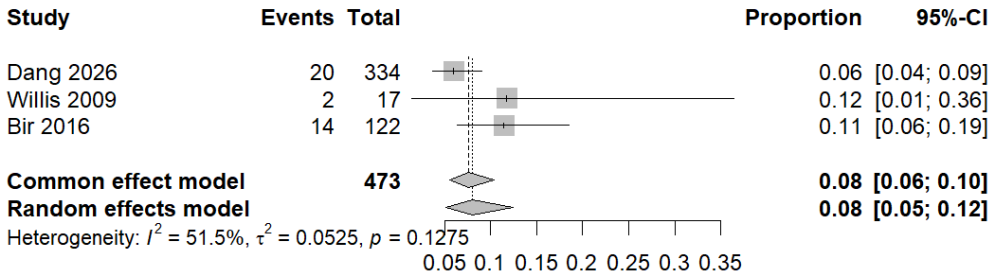

Study Events Total Proportion 95%-CI
Dang 2026 20 334 0.06 [0.04; 0.09]
Willis 2009 2 17 0.12 [0.01; 0.36]
Bir 2016 14 122 0.11 [0.06; 0.19]
Common effect model 473 0.08 [0.06; 0.10]
Random effects model 0.08 [0.05; 0.12]
Heterogeneity: I^2 = 51.5%, τ^2 = 0.0525, p = 0.1275
0.05 0.1 0.15 0.2 0.25 0.3 0.35

Fig. 4 Forest plots of pooled outcomes following endoscopic third ventriculostomy (ETV) consisting of (**a**) success rate, (**b**) mortality rate, (**c**) revision rate, (**d**) total complications, (**e**) infection, and (**f**) other complications

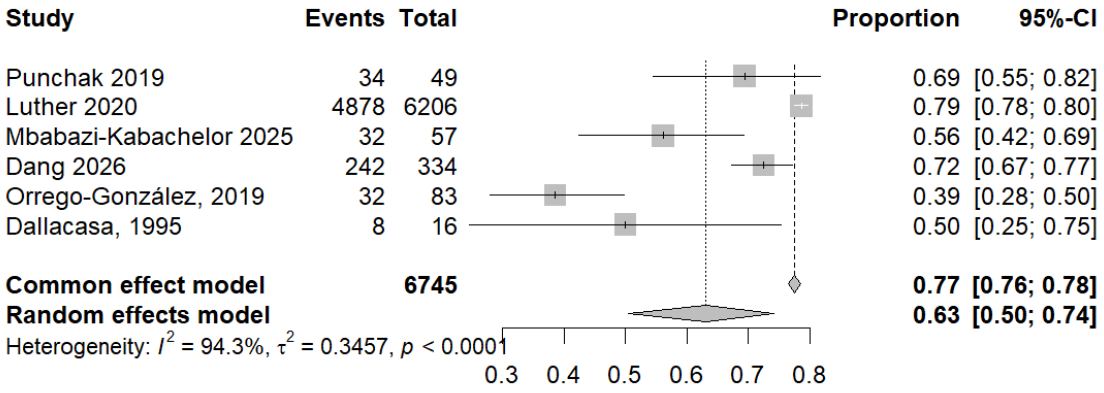
Table 3 Single-Arm Meta-Analysis Summary of ETV Outcomes

Outcome	Studies	n	Proportion (Random Effects)	95% CI
Success Rate	11	5,741	0.51	0.43 – 0.60
Mortality Rate	9	7,228	0.07	0.03 – 0.14
Revision Rate	7	743	0.45	0.30 – 0.62
Total Complication	6	738	0.25	0.14 – 0.40
Infection	4	213	0.08	0.05 – 0.12
Other Complication	3	473	0.08	0.05 – 0.12

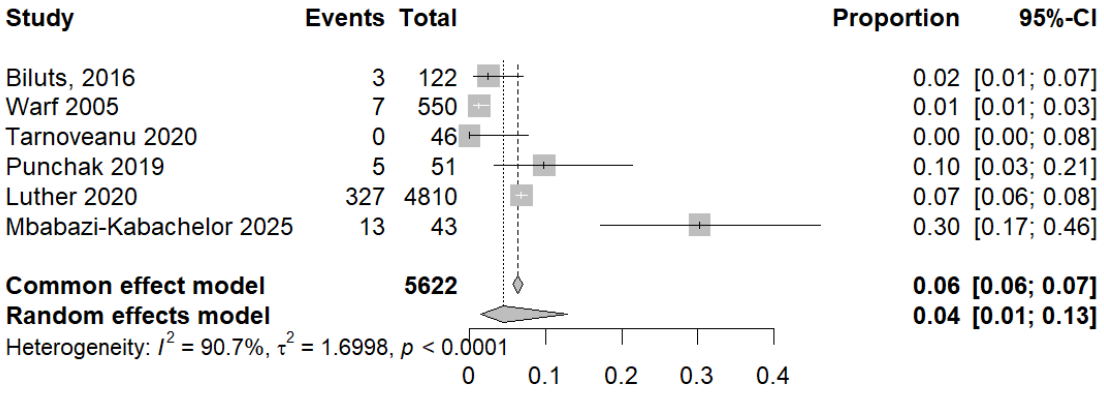
Eleven studies involving 5,741 patients reported treatment success after ETV. The pooled success rate was 51% (95% CI 43–60%), although heterogeneity was considerable ($I^2 = 90.2\%$). Mortality data from nine studies (n = 7,228) showed a pooled mortality rate of 7% (95% CI 3–14%). Seven studies reported revision procedures, yielding a pooled revision rate of 45% (95% CI 30–62%). The pooled overall complication rate was 25% (95% CI 14–40%). Infectious complications occurred in 8% of patients (95% CI 5–12%), with no evidence of heterogeneity ($I^2 = 0\%$). Other complications were also observed in approximately 8% of cases (95% CI 5–12%) (**Table 3**).

The pooled event rates following VPS, including success rate, mortality rate, revision rate, total complications, infection, shunt obstruction, and other complications, are presented in **Fig. 5** and summarized in **Table 4**.

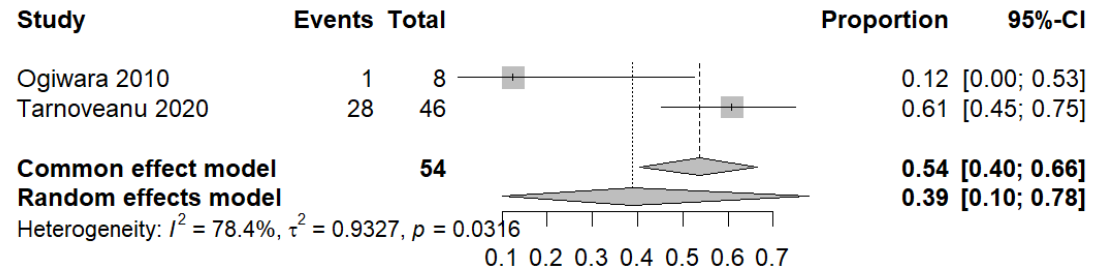
a.


Study
Events
Total
Proportion
95%-CI
Punchak 2019 34 49 0.69 [0.55; 0.82]
Luther 2020 4878 6206 0.79 [0.78; 0.80]
Mbabazi-Kabachelor 2025 32 57 0.56 [0.42; 0.69]
Dang 2026 242 334 0.72 [0.67; 0.77]
Orrego-González, 2019 32 83 0.39 [0.28; 0.50]
Dallacasa, 1995 8 16 0.50 [0.25; 0.75]
Common effect model 6745 0.77 [0.76; 0.78]
Random effects model 0.63 [0.50; 0.74]
Heterogeneity: I^2 = 94.3%, τ^2 = 0.3457, p < 0.0001
0.3 0.4 0.5 0.6 0.7 0.8

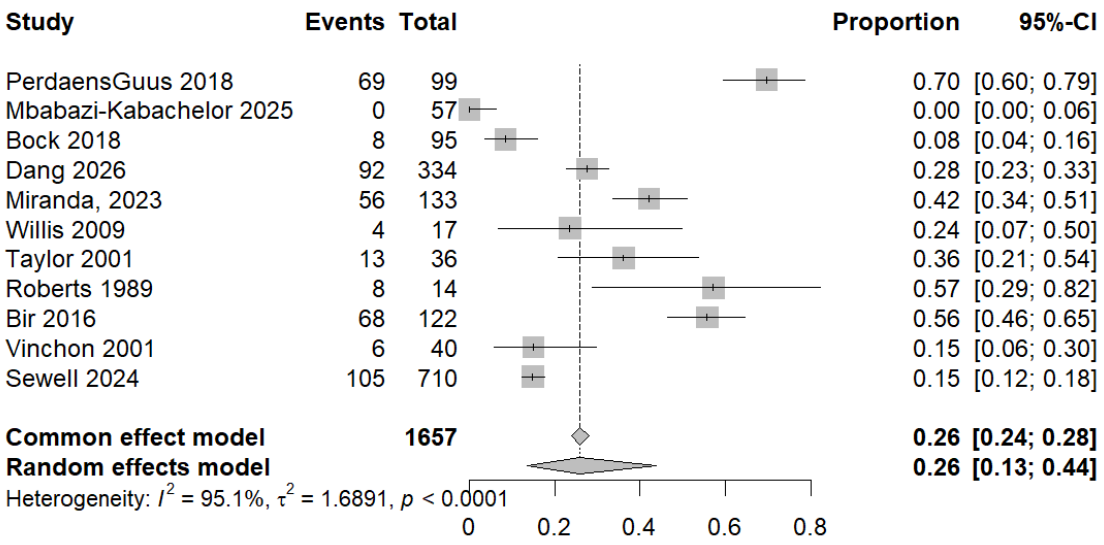
b.


Study
Events
Total
Proportion
95%-CI
Biluts, 2016 3 122 0.02 [0.01; 0.07]
Warf 2005 7 550 0.01 [0.01; 0.03]
Tarnoveanu 2020 0 46 0.00 [0.00; 0.08]
Punchak 2019 5 51 0.10 [0.03; 0.21]
Luther 2020 327 4810 0.07 [0.06; 0.08]
Mbabazi-Kabachelor 2025 13 43 0.30 [0.17; 0.46]
Common effect model 5622 0.06 [0.06; 0.07]
Random effects model 0.04 [0.01; 0.13]
Heterogeneity: I^2 = 90.7%, τ^2 = 1.6998, p < 0.0001
0 0.1 0.2 0.3 0.4

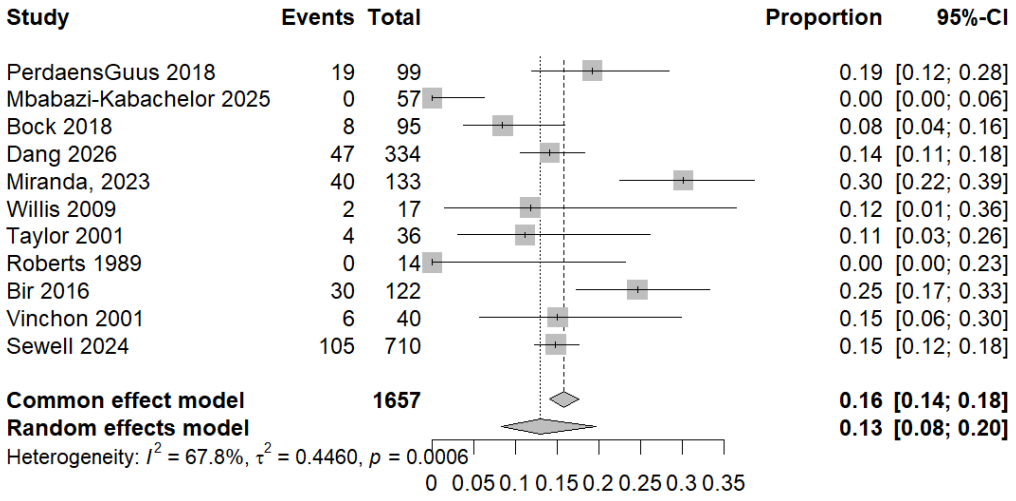
c.


Study
Events
Total
Proportion
95%-CI
Ogiwara 2010 1 8 0.12 [0.00; 0.53]
Tarnoveanu 2020 28 46 0.61 [0.45; 0.75]
Common effect model 54 0.54 [0.40; 0.66]
Random effects model 0.39 [0.10; 0.78]
Heterogeneity: I^2 = 78.4%, τ^2 = 0.9327, p = 0.0316
0.1 0.2 0.3 0.4 0.5 0.6 0.7

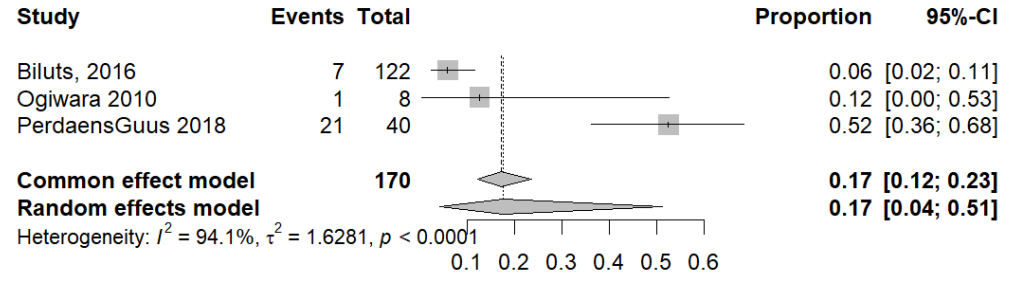
d.


Study Events Total Proportion 95%-CI
PerdaensGuus 2018 69 99 0.70 [0.60; 0.79]
Mbabazi-Kabachelor 2025 0 57 0.00 [0.00; 0.06]
Bock 2018 8 95 0.08 [0.04; 0.16]
Dang 2026 92 334 0.28 [0.23; 0.33]
Miranda, 2023 56 133 0.42 [0.34; 0.51]
Willis 2009 4 17 0.24 [0.07; 0.50]
Taylor 2001 13 36 0.36 [0.21; 0.54]
Roberts 1989 8 14 0.57 [0.29; 0.82]
Bir 2016 68 122 0.56 [0.46; 0.65]
Vinchon 2001 6 40 0.15 [0.06; 0.30]
Sewell 2024 105 710 0.15 [0.12; 0.18]
Common effect model 1657 0.26 [0.24; 0.28]
Random effects model 0.26 [0.13; 0.44]
Heterogeneity: I^2 = 95.1%, τ^2 = 1.6891, p < 0.0001
0 0.2 0.4 0.6 0.8

e.


Study Events Total Proportion 95%-CI
PerdaensGuus 2018 19 99 0.19 [0.12; 0.28]
Mbabazi-Kabachelor 2025 0 57 0.00 [0.00; 0.06]
Bock 2018 8 95 0.08 [0.04; 0.16]
Dang 2026 47 334 0.14 [0.11; 0.18]
Miranda, 2023 40 133 0.30 [0.22; 0.39]
Willis 2009 2 17 0.12 [0.01; 0.36]
Taylor 2001 4 36 0.11 [0.03; 0.26]
Roberts 1989 0 14 0.00 [0.00; 0.23]
Bir 2016 30 122 0.25 [0.17; 0.33]
Vinchon 2001 6 40 0.15 [0.06; 0.30]
Sewell 2024 105 710 0.15 [0.12; 0.18]
Common effect model 1657 0.16 [0.14; 0.18]
Random effects model 0.13 [0.08; 0.20]
Heterogeneity: I^2 = 67.8%, τ^2 = 0.4460, p = 0.0006
0 0.05 0.1 0.15 0.2 0.25 0.3 0.35

f.


Study Events Total Proportion 95%-CI
Biluts, 2016 7 122 0.06 [0.02; 0.11]
Ogiwara 2010 1 8 0.12 [0.00; 0.53]
PerdaensGuus 2018 21 40 0.52 [0.36; 0.68]
Common effect model 170 0.17 [0.12; 0.23]
Random effects model 0.17 [0.04; 0.51]
Heterogeneity: I^2 = 94.1%, τ^2 = 1.6281, p < 0.0001
0.1 0.2 0.3 0.4 0.5 0.6

g.

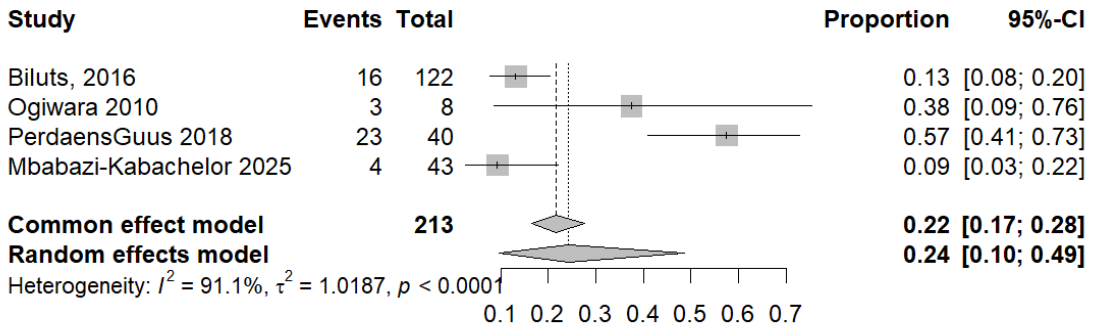


Fig. 5 Forest plots of pooled event rates following ventriculoperitoneal shunting (VPS), consisting of (**a**) treatment success rate, (**b**) mortality, (**c**) revision procedures, (**d**) overall complications, (**e**) infectious complications, (**f**) shunt obstruction, and (**g**) other complications.

Table 4 Single-Arm Meta-Analysis Summary of VPS Outcomes

Outcome	Studies	n	Proportion (Random Effects)	95% CI
Success Rate	6	6,745	0.63	0.50 – 0.74
Mortality Rate	6	5,622	0.04	0.01 – 0.13
Revision Rate	2	54	0.39	0.10 – 0.78
Total Complication	11	1,657	0.26	0.13 – 0.44
Infection	3	170	0.13	0.08 – 0.20
Obstruction	3	170	0.17	0.04 – 0.51
Other Complication	4	213	0.24	0.10 – 0.49

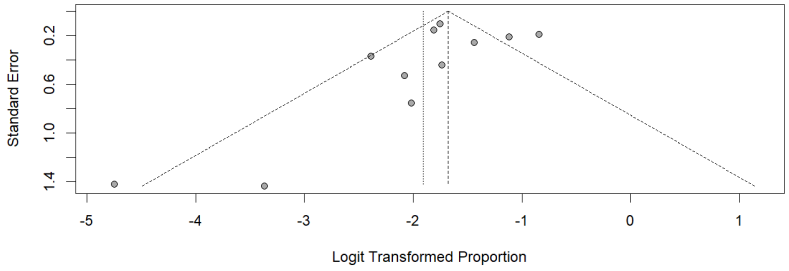
Six studies involving 6,745 patients contributed to the success-rate analysis. VPS demonstrated a pooled success rate of 63% (95% CI 50–74%), with substantial between-study heterogeneity (I^2 = 94.3%). The pooled mortality rate was 4% (95% CI 1–13%), based on six studies including 5,622 patients. Revision procedures were reported in two studies, with a pooled revision rate of 39% (95% CI 10–78%). The overall complication rate following VPS placement was 26% (95% CI 13–44%). Infectious complications occurred in 13% of patients (95% CI 8–20%), whereas shunt obstruction was reported in 17% (95% CI 4–51%). Other complications occurred in 24% of patients (95% CI 10–49%) **(Table 4)**.

Comparison of Single-Arm Outcomes

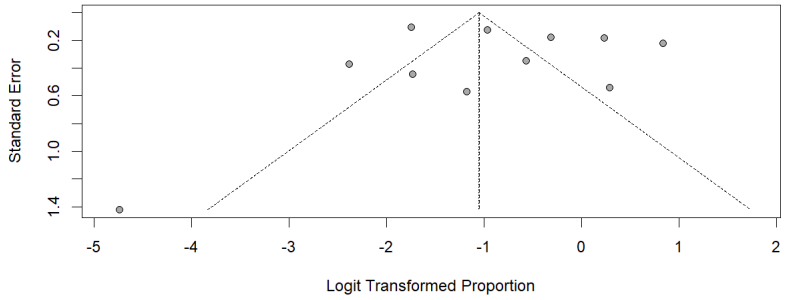
Although direct comparative analyses did not reveal statistically significant differences between ETV and VPS, descriptive comparison of pooled proportions suggested a higher treatment success rate with VPS (63% vs. 51%) and a lower mortality rate (4% vs. 7%). Revision rates were similarly high in both groups (45% for ETV and 39% for VPS), while overall complication rates were nearly identical (25% vs. 26%). Because these estimates originate from separate single-arm analyses and are subject to substantial heterogeneity, they should not be interpreted as evidence of the superiority of one intervention over the other.

Publication Bias

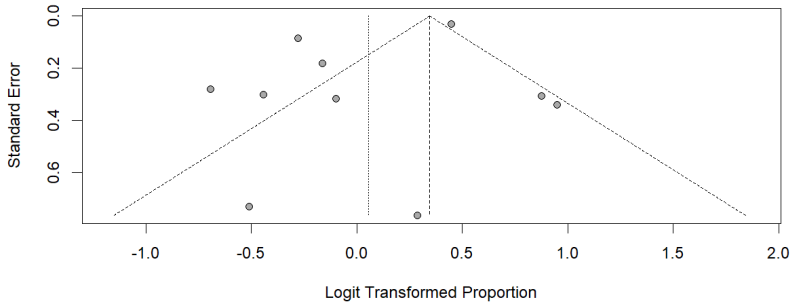
Visual inspection of funnel plots revealed mild asymmetry for ETV success outcomes and slight left-sided asymmetry for VPS mortality and complication outcomes, suggesting the possibility of publication bias among smaller studies. Formal statistical assessment was not performed because most outcomes included fewer than ten studies.



a



b



c

Fig. 6 Funnel plots of (a) VPS infection rate, (b) VPS total complication rate, and (c) ETV success rate

Heterogeneity

Substantial heterogeneity was observed across most pooled analyses, with I^2 values frequently exceeding 75%. Potential contributors include variations in patient age, etiology, and severity of post-inflammatory hydrocephalus, surgical expertise, follow-up duration, and outcome definitions. Consequently, pooled estimates should be interpreted with caution.

Discussion

Principal Findings

This systematic review and meta-analysis of 22 studies encompassing 13,778 children found no statistically significant difference between endoscopic third ventriculostomy (ETV) and ventriculoperitoneal shunting (VPS) for treatment success (RR 0.98, 95% CI 0.73–1.31), overall complications (RR 2.09, 95% CI 0.17–25.27), or mortality (RR 1.24, 95% CI 0.68–2.26) in pediatric post-inflammatory hydrocephalus [3,4,6,7,8,9,10,12,18,19,21,22,23,27,28,31,32,34,35,36,38,39]. Single-arm pooled estimates suggested numerically lower infection (8% vs 13%) and mortality (4% vs 7%) with ETV, though revision rates remained high in both groups (45% vs 39%) [3,4,6,7,8,9,10,12,21,22,23,31,32,34,35,36,38,39]. These findings should be interpreted within the context of the broader ETV-versus-VPS literature, much of which similarly struggles with limited head-to-head data and substantial heterogeneity.

Consistency with Prior Comparative Meta-Analyses

Our null comparative findings align closely with several recent systematic reviews. Pande et al. found no significant difference in failure rate between ETV and VPS in either randomized trials (RR 1.48, 95% CI 0.85–2.59) or cohort studies (RR 1.17, 95% CI 0.89–1.53), though complication rates diverged by study design—non-significant in RCTs (RR 1.34, 95% CI 0.50–3.59) but significantly lower with ETV in prospective cohorts (RR 0.47, 95% CI 0.30–0.78) [24]. This design-dependent discrepancy aligns with our own observation that the pooled complication estimate carried an extremely wide and uncertain confidence interval, likely reflecting the small number of comparative studies (n = 2) available for that outcome. Similarly, a meta-analysis restricted to African treatment centers found no statistically significant difference between ETV and VPS outcomes (OR 0.27, 95% CI −0.39 to 0.94, p = 0.42), reinforcing that the equipoise observed in our predominantly African- and Ugandan-derived cohorts

is not an isolated finding but a recurring pattern in low-resource settings [15].

In contrast, Minta and colleagues reported that although success rates were statistically similar between ETV (81.8%) and VPS (86.7%) (RR 0.84, 95% CI 0.80–0.90, p = 0.93), VPS carried a substantially higher complication burden (27.1% vs 4.6%; RR 0.76 favoring ETV, 95% CI 0.42–1.38) [20]. This finding diverges somewhat from our comparative complication estimate, which was directionally unfavorable to ETV despite its extreme imprecision, illustrating how complication definitions, follow-up duration, and case-mix can materially alter comparative conclusions even when success-rate findings converge. A 2025 preprint meta-analysis of nine studies (13,509 children) similarly reported that ETV was associated with lower infection and shunt-dependency rates, particularly in children older than one year and those with obstructive hydrocephalus, along with better long-term cognitive and quality-of-life outcomes, while VPS retained a slight short-term success advantage in post-hemorrhagic etiologies [29]. Although our review did not assess cognitive or quality-of-life endpoints, this raises the possibility that ETV's theoretical advantage in reducing device dependency may manifest more clearly in longer-term or patient-centered outcomes not fully captured by short-term success and complication metrics.

Etiology-Specific Comparisons

Because our review isolated post-inflammatory hydrocephalus specifically, comparison with etiology-matched literature is particularly informative. A meta-analysis of 369 children with tuberculous meningitis hydrocephalus, an infectious etiology closely related to our post-infectious subgroup, reported no significant differences in success (OR 0.72, 95% CI 0.45–1.14), complications (OR 0.59, 95% CI 0.08–4.17), mortality (OR 0.78, 95% CI 0.23–2.65), or infection (OR 0.52, 95% CI 0.09–2.87) between ETV and VPS, while cautioning that broad confidence intervals and only five included studies introduced substantial uncertainty [11]. This convergence across two etiology-specific reviews of infection-related hydrocephalus suggests that the equipoise we observed is not simply an artifact of our particular dataset but may be a genuine feature of infectious/inflammatory hydrocephalus, where inflammatory scarring of basal cisterns and ependymal surfaces may limit ETV efficacy regardless of comparator.

Notably, this pattern contrasts with etiologies where the cause of hydrocephalus is purely obstructive rather than inflammatory. A meta-analysis of 917 children with posterior fossa tumor-related hydrocephalus found comparable mortality (OR 0.49, 95% CI 0.14–1.73) and reoperation rates (OR 0.65, 95% CI 0.43–1.00) between ETV and VPS, but ETV was associated with significantly lower rates of infection (OR 0.15, 95% CI 0.03–0.73) and intracranial bleeding (OR 0.40, 95% CI 0.17–0.97) [17]. Likewise, a review of five RCTs in obstructive hydrocephalus found a significant ETV advantage for postoperative infection (RR 0.11, 95% CI 0.04–0.33) and blockage rate (RR 0.15, 95% CI 0.03–0.75), despite no significant difference in operative success or mortality [26]. Taken together, these etiology-specific comparisons suggest that ETV's infection-reduction benefit may be more pronounced and statistically detectable in obstructive,

non-inflammatory hydrocephalus, where cerebrospinal fluid pathways are mechanically blocked rather than diffusely compromised by prior infection or hemorrhage. This distinction may partly explain why our post-inflammatory cohort, despite numerically favoring ETV for infection, did not reach statistical significance in the pooled comparative analysis.

Influence of Geographic and Resource Setting

A substantial proportion of our included cohorts originated from sub-Saharan Africa, where post-infectious hydrocephalus is disproportionately prevalent, and endoscopic third ventriculostomy combined with choroid plexus cauterization (ETV+CPC) has been extensively studied as a shunt-avoidance strategy [12,19,28,35,38]. A comprehensive meta-analysis of 16 studies found that the pooled ETV+CPC failure rate differed significantly by geographic income level, with lower-middle-income countries demonstrating a lower failure rate (32%, 95% CI 28–36%) than high-income countries (53%, 95% CI 47–60%) ($p < 0.01$), despite both being classified as low-quality evidence overall [2]. This geographic heterogeneity offers a plausible explanation for part of the substantial between-study heterogeneity (I^2 frequently exceeding 75%) observed in our pooled estimates, since our dataset combined cohorts from both high-income settings and low-resource settings without stratifying by income level. A retrospective case series of 76 patients from Guinea further illustrated real-world outcomes of ETV (with or without CPC) in a low-income, mixed post-infectious population, reporting a 61% global success rate at a mean follow-up of 28 months alongside 26 deaths among the cohort (approximately 34%) [33]. This underscores that procedure-specific outcomes for the same intervention can vary dramatically depending on healthcare infrastructure, perioperative monitoring capacity, and patient presentation severity, factors that are difficult to fully adjust for in aggregate meta-analytic pooling.

Mechanisms Underlying Persistent Revision and Complication Burden

Our finding of high revision rates in both arms (45% ETV, 39% VPS) is consistent with existing VPS-specific literature describing shunt obstruction and infection as the dominant drivers of shunt failure in infants younger than two years [13]. Complication-focused reviews of VPS in children have similarly emphasized that, despite decades of technical refinement, no consensus exists on optimal shunt workup and management strategies, with mechanical failure, infection, and functional failure remaining the three dominant complication categories requiring revision [5]. This evidence supports our interpretation that neither ETV nor VPS meaningfully reduces the burden of reintervention in post-inflammatory hydrocephalus, reinforcing the clinical message that procedure selection should be guided by anatomical and contextual factors rather than an assumption of one technique's categorical superiority.

Publication Bias

Visual asymmetry in funnel plots for ETV success rate, VPS mortality, and VPS total complication suggests the possibility of small-study effects, consistent with selective reporting of favorable outcomes in smaller institutional series. This asymmetry may lead to overestimation of success rates and underestimation of complication rates in both treatment arms. The large Luther 2020

administrative dataset (n > 10,000 patients combined), which would anchor funnel plots toward the center, likely mitigates but does not eliminate this risk [18].

Strengths and Limitations

This study has several strengths. It provides a focused assessment of ETV versus VPS in pediatric post-inflammatory hydrocephalus, an etiologically distinct population that is often underrepresented in broader hydrocephalus reviews. The comprehensive search of nine databases, prospective PROSPERO registration, inclusion of 22 studies involving 13,778 children, and separate analysis of direct comparative and single-arm evidence strengthen the methodological scope of this review. In addition, risk-of-bias assessment was independently performed by two reviewers, with disagreements resolved through consensus or third-reviewer consultation.

Several limitations should be considered. Direct head-to-head evidence was limited for several outcomes, resulting in imprecise estimates and wide confidence intervals, particularly for overall complications. Substantial heterogeneity was observed across pooled analyses, potentially reflecting differences in patient characteristics, hydrocephalus etiology and severity, surgical expertise, follow-up duration, outcome definitions, and geographic or healthcare-resource settings. The predominance of observational studies also limits causal inference, while funnel-plot asymmetry suggests possible small-study effects. Finally, the use of aggregate data prevented adjustment for clinically relevant factors such as age, hydrocephalus subtype, causative organism, ETV success score, and follow-up duration.

Future Research Directions

This meta-analysis highlights three priorities for future research. First, a prospective, adequately powered randomized controlled trial comparing ETV (±CPC) and VPS in pediatric PIH across multiple geographic settings is urgently needed to provide unconfounded comparative evidence; the International Infant Hydrocephalus Study consortium provides a potential organizational framework. Second, future studies must standardize outcome definitions, particularly the composite failure endpoint and its time horizon, to enable meaningful pooling. Third, an individual patient data meta-analysis incorporating ETV Success Score (ETVSS), hydrocephalus type, causative organism, and follow-up duration would allow subgroup-level treatment recommendations currently unachievable with aggregate data.

Conclusion

This systematic review and meta-analysis show no significant differences in success rate, complications, and mortality between ETV and VPS for pediatric post-inflammatory hydrocephalus. However, single-arm pooling may show lower infection rates and mortality for ETV. These results should be interpreted cautiously, given marked heterogeneity and limited head-to-head data. Therefore, while no statistically significant differences have been demonstrated, the potential for clinically significant differences remains.

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Ethics approval
Ethics approval was not required because this systematic review and meta-analysis used data from previously published studies and did not involve direct interaction with human participants or access to identifiable individual-level data. The study was conducted and reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 statement.

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Not applicable

Consent to participate
Not applicable

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Data availability
The data supporting the findings of this systematic review and meta-analysis are available from the corresponding author upon reasonable request.

Code availability
The statistical code used for the analyses is available from the corresponding author upon reasonable request.

Supplementary Files

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- PRISMA2020checklist.pdf