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Endoscopic Third Ventriculostomy with Choroid Plexus Cauterization versus Ventriculoperitoneal Shunt for Pediatric Hydrocephalus: A Systematic Review and Meta-Analysis

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ABSTRACT

Background. Pediatric hydrocephalus is a serious neurological condition requiring effective surgical intervention to prevent long-term morbidity and mortality. Two primary approaches are commonly employed: ventriculoperitoneal (VP) shunt and endoscopic third ventriculostomy with choroid plexus cauterization (ETV+CPC), each presenting distinct advantages and limitations, particularly in resource-limited healthcare settings. This study aimed to compare the effectiveness and safety of both procedures in children with hydrocephalus.
Methods. A systematic review and meta-analysis of 10 observational studies retrieved from PubMed and ScienceDirect was performed. Study selection followed the PRISMA 2020 guideline, and statistical analyses were conducted using both fixed- and random-effects models. Categorical outcomes were pooled as risk ratios (RR) and the continuous outcome (time to failure) as mean difference (MD), each with 95% confidence intervals (CI). Heterogeneity was assessed using the I^2 statistic, and sensitivity and publication-bias analyses were undertaken.
Results. There was no significant difference in procedural success (RR 0.96; 95% CI 0.84–1.09; p = 0.52) or mortality (RR 1.01; 95% CI 0.55–1.83; p = 0.98) between the two procedures. However, ETV+CPC was associated with significantly fewer complications (RR 0.42; 95% CI 0.21–0.83; p = 0.02) and a longer time to failure (MD 3.62 months; 95% CI 0.12–6.45; p = 0.04). Revision rates showed no significant difference (RR 1.30; 95% CI 0.72–2.33; p = 0.38).
Conclusion. ETV+CPC offers comparable effectiveness to VP shunt with superior safety and durability profiles, making it a viable alternative, particularly in settings with limited resources.

INTRODUCTION

Hydrocephalus is a critical neurological condition characterized by the abnormal accumulation of cerebrospinal fluid (CSF) within the cerebral ventricles, resulting in raised intracranial pressure, ventricular dilatation, and detrimental effects on the surrounding brain tissue; in children it can lead to macrocephaly, neurological retardation, developmental impairment, and death if not managed adequately. Its etiology is highly heterogeneous, ranging from central nervous system infection (e.g., meningitis) and intraventricular hemorrhage in premature infants to congenital malformations such as aqueductal stenosis or myelomeningocele that mechanically obstruct CSF flow, with obstructive conditions such as aqueductal stenosis frequently being the primary target for surgical techniques that create an alternative CSF pathway.[1,2]

In clinical practice, the two principal surgical methods used to manage hydrocephalus are the VP shunt and ETV+CPC (endoscopic third ventriculostomy with choroid plexus cauterization). The VP shunt diverts CSF from the ventricles to the peritoneal cavity through a catheter and valve and has long been the standard of care owing to its technical simplicity and its ability to treat various types of hydrocephalus; however, the implanted device is highly susceptible to infection, mechanical obstruction, catheter malfunction, over-drainage, and system failure requiring repeated revision, and in many developing countries where resources for surgical revision, routine radiological monitoring, and referral to neurosurgical centers are severely limited shunt failure may not be

addressed promptly, increasing morbidity or mortality.[2,3] Reports indicate that shunt complications may reach 20–40% in the hospital setting; analysis of pediatric VP shunt malfunction showed rates as high as 54.1% (with infection in 16.2%) at a teaching hospital in Brazil, frequently with catheters placed by residents, reflecting the challenge of technical training in limited facilities; global systematic reports state that complications in developing countries may range from 1% to 40%; and a local Indian study of 198 patients found an overall complication incidence of 28.8% (revision 21.2%, blockage 7.6%, catheter migration 5.05%, infection 4.5%, other malfunction 8.6%), while shunt infection can progress to meningitis or ventriculitis, increasing morbidity and mortality.[3,4-6]

Conversely, ETV+CPC offers a more physiological approach: ETV creates an opening (stoma) in the floor of the third ventricle to allow CSF to flow into the subarachnoid cisterns, while CPC reduces CSF production by cauterizing the choroid plexus, and by not requiring an implanted device it can reduce implant-related complications, dependence on device revision, and the long-term burden on the health-care system. In resource-limited settings ETV+CPC becomes an attractive alternative; a study in a low-resource hospital in Tanzania reported a 91% success rate for ETV/CPC at 3 months without the need for shunt placement, demonstrating that the technique can be applied even in limited facilities provided that minimal resources (an endoscope and a trained team) are available.[1,7] Previous studies have evaluated key variables such as procedural success, revision rate, postoperative complications, time to failure (TTF), and post-procedural mortality; for example, Kulkarni et al. reported no significant cognitive difference between the ETV+CPC and VPS groups in Ugandan infants while also observing rates of re-failure and complications, and Warf demonstrated that ETV+CPC can avoid shunt dependence in approximately 80% of patients ≥2.5 months of age regardless of previous CSF diversion (versus ~59% in patients <2.5 months without prior intervention), with long-term success in maintaining stoma patency when the stoma remained open beyond the early critical phase.[8,9]

Integrating this empirical evidence and considering the limitations of health-care systems in many regions particularly facilities lacking rapid access to re-operation, routine imaging, neurosurgical teams, and robust referral systems the present study aimed to perform a meta-analysis of the effectiveness and safety of ETV+CPC versus VP shunt in children, evaluating procedural success, revision rate, postoperative complications, time to failure (TTF), and mortality, and examining predictors of success such as patient age at intervention and hydrocephalus etiology. The expectation of this study is to generate clinical and policy recommendations that are adaptive to facility conditions, particularly in pediatric neurosurgical services with limited resources, so that intervention strategies can be selected not only on the basis of clinical evidence but also on the capacity of the service system to ensure long-term monitoring and revision when required.[5,10,11]

METHODS

Study design

This was a systematic review and meta-analysis aimed at comparing the effectiveness and safety of ETV+CPC and shunt procedures in children. The study combined and analyzed data from previously published studies to evaluate the clinical outcomes, success rate, and complications of both procedures. The data used in this meta-analysis were collected through a systematic search of relevant scientific databases, with predefined inclusion and exclusion criteria to ensure the validity and reliability of the results. The study flow followed the PRISMA 2020 chart, and the clinical question was framed using the PICO (Population, Intervention, Comparison, Outcome) format.

Eligibility criteria

Inclusion criteria were: (1) studies that evaluated and compared the clinical outcomes of ETV+CPC and shunt in children; (2) studies with a cohort, randomized controlled trial, or retrospective analysis design reporting relevant data; (3) studies presenting data on procedural success, complications, and revision rate; and (4) articles available in English or another language with an accessible translation. Exclusion criteria were: (1) studies with an inappropriate population; (2) studies that did not directly compare ETV+CPC and shunt; (3) studies with incomplete data or without the primary outcomes analyzed; (4) case reports, review articles, conference abstracts, or editorials; and (5) articles with restricted access that could not be fully downloaded for analysis.

Search strategy and study selection

A systematic literature search was conducted in electronic databases including PubMed, Scopus, Web of Science, and Cochrane Library. The keywords used combined the terms “ETV+CPC”, “shunt”, “hydrocephalus”, “infants”, and “low to middle income countries”. Study selection was performed in two stages initial screening based on title and abstract, followed by full-text review. Two independent reviewers assessed the eligibility of each study, and disagreements were resolved through discussion or consultation with a third reviewer.

Data extraction and outcome measures

Data from studies meeting the criteria were extracted systematically using a standardized format covering study characteristics (design, location, sample size), patient characteristics (age, hydrocephalus etiology), the intervention administered (ETV+CPC or shunt), and the primary clinical outcomes of procedural success, revision rate, and complications. The independent variable was the type of procedure performed (ETV+CPC vs. shunt). The dependent variables were procedural success (success/failure), revision rate (yes/no), post-procedural

complications (present/absent), mortality (alive/dead), and time to failure (number of months until failure). Procedural success was defined as a state in which the patient did not require re-intervention within the follow-up period defined in the study. Time to failure (TTF) was defined as the interval from the initial procedure to the first failure requiring re-intervention, measured as an indicator of medium- to long-term durability.

Statistical analysis

Extracted data were analyzed using statistical software such as RevMan or STATA. Analysis was performed using inverse-variance weighting, with the weight of each study determined by its sample size and the reported variability of results. A fixed-effect model was used when between-study heterogeneity was low, whereas a random-effects model was applied when heterogeneity was high. Heterogeneity was assessed using the I^2 statistic, with I^2 <25% indicating low, 25–50% moderate, and >50% high heterogeneity. When heterogeneity was significant, subgroup analysis was performed to identify contributing factors such as hydrocephalus etiology, patient age, or methodological differences between studies.

Results of the meta-analysis were presented as forest plots displaying the effect estimate of each study with its 95% confidence interval. For categorical variables such as procedural success and complications, analysis was performed by calculating the risk ratio (RR) or odds ratio (OR); for numerical variables such as time to failure, mean difference (MD) or standardized mean difference (SMD) analysis was used. Sensitivity analysis was performed to assess the stability of results by repeating the analysis after excluding studies with a high risk of bias or substantially different methodology. Publication bias was evaluated using a funnel plot and the Egger or Begg test; where indicated, trim-and-fill analysis was applied to correct the estimated effect.

RESULTS

Study selection

In the initial stage of the literature selection process, a systematic search was performed of two primary databases, PubMed and ScienceDirect. This search yielded 1,354 articles, comprising 247 articles from PubMed and 1,107 articles from ScienceDirect. All identified articles were compiled and de-duplicated. After removing duplicate entries, 842 articles remained and were screened by title and abstract review. At this screening stage, 796 articles were excluded because they were not relevant to the topic, did not include the appropriate intervention, or did not report the desired clinical outcomes. Accordingly, 46 articles were retrieved as full text for further eligibility assessment; all articles entering this stage were fully accessible (n = 0 not retrieved). Of the 46 full-text articles assessed, 36 were excluded reasons being the absence of a direct comparison between ETV+CPC and VP shunt, the absence of numerical data amenable to statistical analysis, and the use of study designs not meeting the inclusion criteria. Finally, 10 studies were selected and included in the qualitative and quantitative analysis of this meta-analysis (Figure 1).

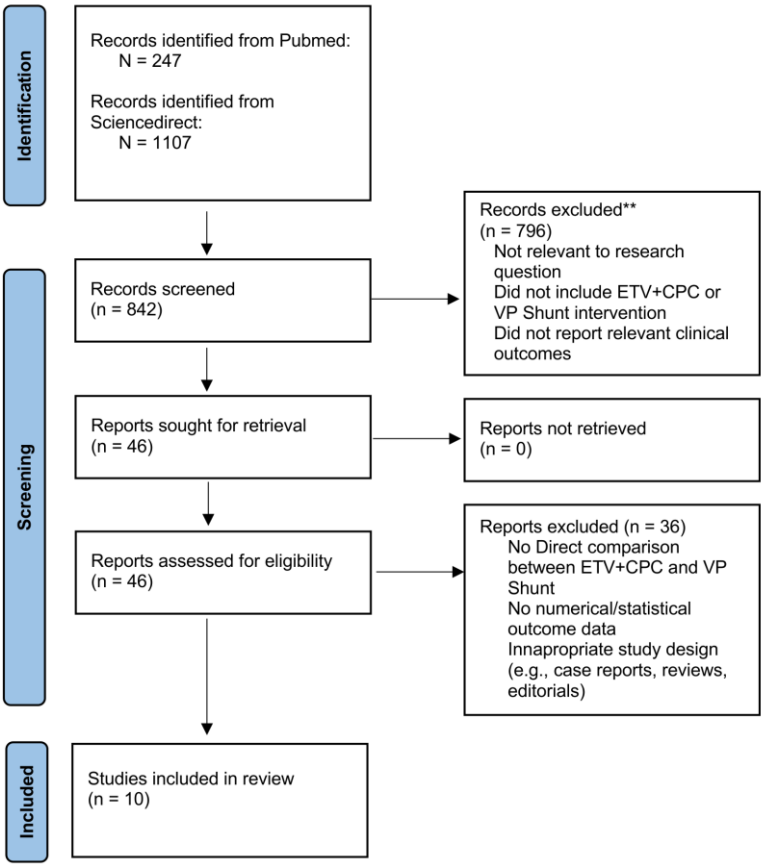


Figure 1. PRISMA 2020 flow diagram.

Study characteristics

Ten studies were included in this meta-analysis, encompassing diverse study designs and geographic locations representing pediatric hydrocephalus populations in both developing and developed countries: most used a retrospective cohort design (Adebayo, Navaei, Izah, Kulkarni, Chimaliro, Cairo),[12-17] while others were prospective cohorts (Warf),[7] registry-based (Pindrik),[18] a multicenter study (Dewan),[19] or a matched cohort (Alali),[20] with most originating from Africa (Nigeria, Uganda, Malawi, DR Congo) and the remainder from Canada, the United States, and Iran, and sample sizes ranging from small studies such as Cairo et al. (3 ETV+CPC and 113 VPS patients) to Pindrik et al.'s large registry-based study of 1,019 patients. Patients were predominantly young children, especially infants under 1 year, with median or mean age at intervention of 2 to 6 months (except Cairo et al., 13.6 months) and etiologies including congenital, post-infectious, and intraventricular-hemorrhage causes and malformations such as myelomeningocele (MMC), several reporting mixed etiologies; follow-up ranged from 6 months (Navaei, Adebayo, Dewan) to more than 5 years (Pindrik) up to 13 years in Cairo et al., with some reporting multiple time points (1, 3, and 5 years, as in Pindrik). The main outcomes were procedural success, revision rate, postoperative complications, and time to failure (TTF), with several studies also reporting mortality (Kulkarni, Izah, Chimaliro, Cairo) and radiological parameters such as FOHR and HC (Dewan), and Warf and Alali explicitly analyzing time to failure in days and months respectively; the characteristics of the included studies are summarized in Table 1.

Table 1. Characteristics of the included studies.

Study	Country	Study design	Sample (ETV+CPC / VPS)	Age at procedure	Hydrocephalus etiology	Follow-up	Main outcomes reported
Adebayo et al., 2021[12]	Nigeria	Retrospective cohort	23 / 22	Median 4 months	Infection, congenital	6 months	Procedural success, complications
Warf et al., 2023[7]	Uganda	Prospective cohort	266 / 82	Mean ~3.5 months	Post-infectious, congenital	Up to 12 months	Procedural success, time to failure
Alali et al., 2025[20]	Canada	Matched retrospective cohort	35 / 39	Median 3 months	IVH, aqueductal stenosis	12 months	Success, revision, complications, TTF

Kulkarni et al., 2017[13]	Canada	Retrospective cohort	51 / 49	Infants <1 year	Congenital	12 months	Success, complications, revision, mortality
Navaei et al., 2018[14]	Iran	Retrospective	22 / 27	Mean 2.1 months	Congenital	6 months	Success, complications, mortality
Izah et al., 2024[15]	Nigeria	Retrospective cohort	17 / 8	Mean 5.5 months	Post-infectious	12 months	Success, complications, TTF
Dewan et al., 2018[19]	USA (multicenter)	Multicenter cohort	18 / 54	Mean 3.4 / 2.9 months	MMC, congenital, IVH	6 months	Success, HC, FOHR
Pindrik et al., 2020[18]	USA & Canada	Registry-based cohort	109 / 910	<24 months	Mixed	1, 3, 5 years	Revision rate, infection
Cairo et al., 2018[16]	DR Congo	Retrospective	3 / 113	Mean 13.6 months	Neonatal sepsis, congenital	13 years	Complications, mortality
Chimaliro et al., 2022[17]	Malawi	Retrospective	58 / 21	Mean 4 months	Mixed	1 year	Complications, mortality

ETV+CPC, endoscopic third ventriculostomy with choroid plexus cauterization; VPS, ventriculoperitoneal shunt; IVH, intraventricular hemorrhage; MMC, myelomeningocele; TTF, time to failure; HC, head circumference; FOHR, frontal and occipital horn ratio.

Procedural success rate

A meta-analysis of the ten studies comparing procedural success of ETV+CPC (597 patients) with VP shunt (1,344 patients) in children with hydrocephalus success generally defined as the absence of a need for re-intervention within the defined follow-up showed no statistically significant difference between the two groups, with an overall risk ratio of 0.96 (95% CI 0.84–1.09; p = 0.52), indicating comparable probability of success, albeit with considerable between-study heterogeneity (I^2 = 66%; p = 0.002) reflecting real variation not explained by chance alone (Figure 2). Individual studies showed contrasting tendencies: Izah et al. (2024)[15] reported an RR of 1.46 favoring ETV+CPC and Pindrik et al. (2020)[18] an RR of 0.71 favoring VP shunt, whereas Warf et al. (2023),[7] Kulkarni et al. (2017),[13] and Alali et al. (2025)[20] reported near-neutral results (RR around 1.0); this heterogeneity was probably driven by differences in study design (prospective vs. retrospective), follow-up duration, the operational definition of success, patient characteristics such as age at procedure and hydrocephalus etiology, and operator experience in performing ETV+CPC.

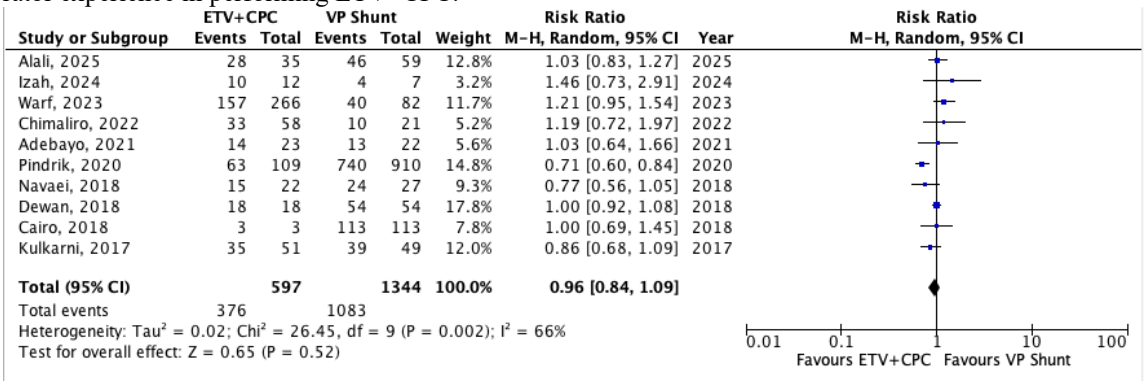


Figure 2. Forest plot of the procedural success rate between ETV+CPC and VP shunt in pediatric patients with hydrocephalus.

Procedural revision rate

Meta-analysis of the procedural revision rate based on seven studies that explicitly reported revision events (518 ETV+CPC and 1,096 VP shunt patients), with revision defined as the need for additional procedures such as re-operation or device replacement due to failure of the primary procedure showed, using a random-effects model, a tendency toward fewer procedural revisions in the ETV+CPC group that did not reach statistical significance, with an RR of 1.30 (95% CI 0.72–2.33; p = 0.38), indicating no strong evidence favoring either procedure (Figure 3). Between-study heterogeneity was very high (I^2 = 86%; p < 0.00001), probably influenced by variation in the definition of revision, follow-up duration, and evaluation criteria some studies recorded only major surgical

revisions while others included minimal or non-invasive interventions with Pindrik et al. (2020)[18] and Chimaliro et al. (2022)[17] contributing substantially because of their large sample sizes and outcome-definition variation, and Navaei et al. (2018)[14] and Izah et al. (2024)[15] reflecting populations with limited access to surgical follow-up that may have caused underreporting; thus, although no significant difference in revision rate was found, interpretation must be undertaken cautiously given the high heterogeneity and potential reporting bias.

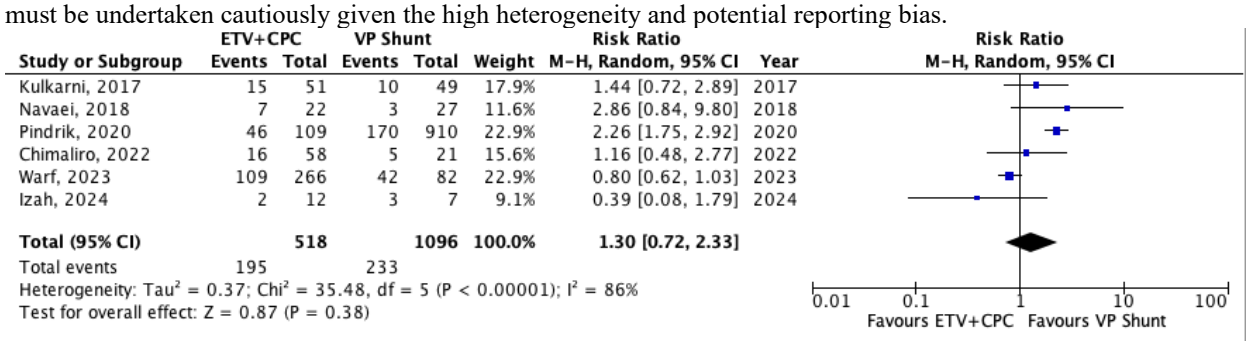


Figure 3. Forest plot of the procedural revision rate between ETV+CPC and VP shunt in pediatric patients with hydrocephalus.

Post-procedural complications

Post-procedural complications reflecting the relative safety of the two procedures and including infection, hemorrhage, neurological disturbance, or mechanical shunt failure requiring medical attention or additional intervention were analyzed using data from nine studies (567 ETV+CPC and 1,258 VP shunt patients), which showed that ETV+CPC was significantly safer than VP shunt, with an RR of 0.42 (95% CI 0.21–0.83; p = 0.02), corresponding to an approximately 58% lower complication risk and demonstrating that ETV+CPC not only provides comparable effectiveness but also offers a better safety profile (Figure 4). Between-study heterogeneity was moderate (I^2 = 49%; p = 0.06), with some studies showing marked differences Alali et al. (2025)[20] and Warf et al. (2023)[7] demonstrated a significant reduction in complication risk with ETV+CPC, whereas Dewan et al. (2018)[19] showed a more neutral result probably owing to differences in complication definitions, reporting approaches, and follow-up duration; overall, from a safety standpoint, ETV+CPC is a relatively more favorable intervention than VP shunt, particularly in pediatric populations at high risk of infection and with limited medical resources.

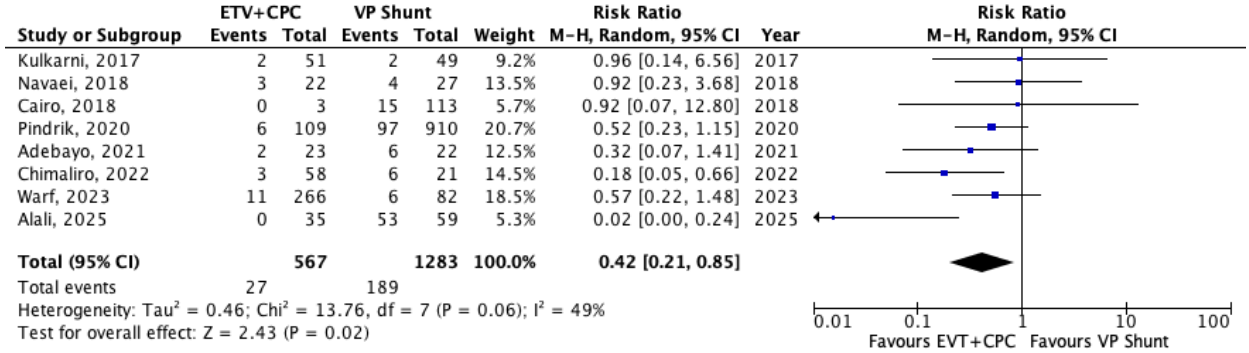


Figure 4. Forest plot of post-procedural complications between ETV+CPC and VP shunt in pediatric patients with hydrocephalus.

Time to failure

Time to failure (TTF), defined as the interval from the initial intervention to the onset of clinical failure requiring re-intervention, is an important parameter of treatment durability; three studies provided quantitative data (mean and standard deviation) amenable to analysis Adebayo et al. (2021),[12] Warf et al. (2023),[7] and Izah et al. (2024)[15] and meta-analysis using an inverse-variance random-effects approach yielded a mean difference of 3.62 months (95% CI 0.12–6.45; p = 0.04), indicating that ETV+CPC patients statistically had a longer failure-free period before requiring revision or additional intervention than those receiving VP shunt (Figure 5). However, heterogeneity was very high (I^2 = 98%), reflecting substantial variation not fully explained by random error and probably driven by differences in study populations, TTF measurement methodology, and time units (days, weeks, or months) Warf et al.[7] showed a higher mean TTF in the VP shunt group, whereas Adebayo and Izah[12,15] showed a TTF advantage for ETV+CPC suggesting that hydrocephalus etiology, patient age, and operator experience may affect durability; nonetheless, despite the limited number of studies and high heterogeneity, these findings indicate that ETV+CPC has potential superiority in providing medium-term stability without additional intervention, making it a viable alternative particularly in populations with limited access to surgical revision services.

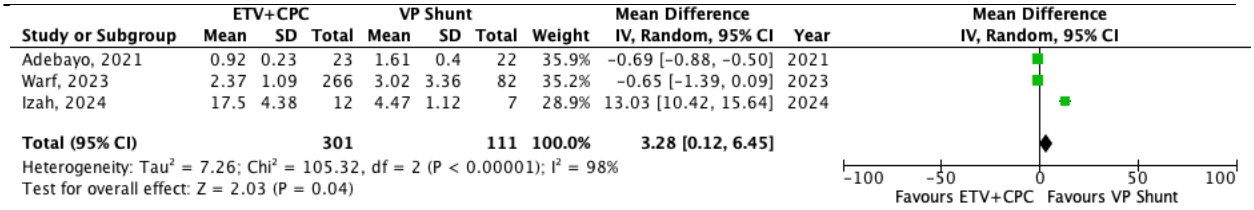


Figure 5. Forest plot of time to failure (in months) between ETV+CPC and VP shunt in pediatric patients with hydrocephalus.

Mortality

Mortality, a critical outcome in evaluating the safety of hydrocephalus procedures in children, was reported in eight studies, with 20 deaths among 470 patients in the ETV+CPC group and 11 deaths among 710 patients in the VP shunt group, showing no statistically significant difference between the two RR 1.01 (95% CI 0.55–1.83; p = 0.98) so post-procedural mortality was not significantly influenced by the choice of procedure (Figure 6). Between-study heterogeneity was very low ($I^2 = 0\%$), indicating consistency across studies, although most studies had very low or zero mortality events, rendering some estimates not estimable (Chimaliro et al. [2022],[17] Dewan et al. [2018],[19] and Izah et al. [2024][15]); Navaei et al. (2018)[14] and Cairo et al. (2018)[16] recorded higher mortality in the VP shunt group, whereas Warf et al. (2023)[7] showed relatively similar numbers of deaths between groups, with deaths related to infectious complications, severe underlying conditions, and delayed re-intervention due to primary procedure failure. These results indicate that both ETV+CPC and VP shunt have comparable short- to medium-term survival profiles, although further evaluation with longer follow-up and prospective designs is needed to assess long-term mortality more comprehensively.

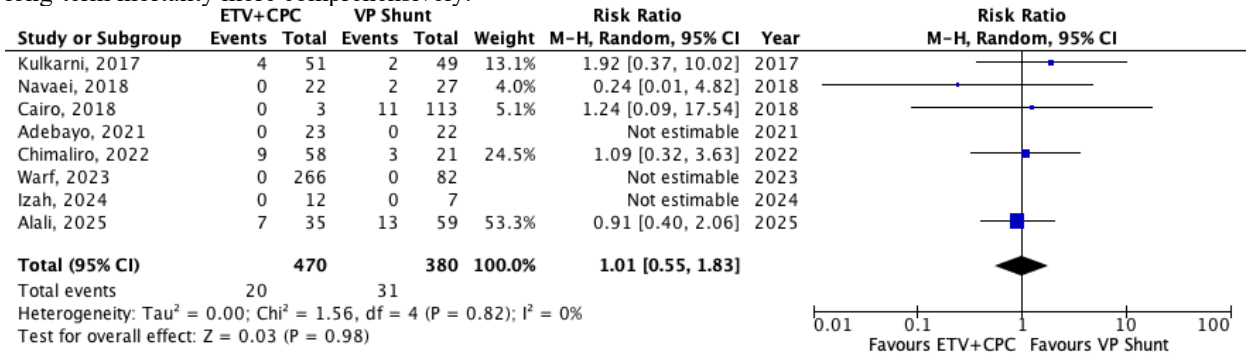


Figure 6. Forest plot of mortality between ETV+CPC and VP shunt in pediatric patients with hydrocephalus.

Sensitivity analysis

Sensitivity analysis was performed to evaluate the stability of the meta-analysis results and to ensure that the main findings were not dominated by one or a few studies with a high risk of bias or deviant methodological characteristics. This approach is important in meta-analyses of surgical interventions, where between-study heterogeneity is often high owing to variation in populations, procedural protocols, and reporting quality. In this study, sensitivity analysis was conducted by excluding studies with a high risk of bias, very small sample sizes, or designs deviating substantially from the others. For example, Cairo et al. (2018),[16] with only three patients in the ETV+CPC group and conducted under conditions of extreme resource limitation, as well as studies with "not estimable" data on some outcomes, were excluded sequentially to assess their impact on the pooled result. After stepwise exclusion, the meta-analysis results remained consistent in the direction of effect across almost all main outcomes, including procedural success, revision rate, complications, and time to failure. When Cairo et al. was excluded from the complication analysis, the risk ratio remained significant with minimal change to the confidence interval, indicating that the result did not depend on that study. For time to failure, heterogeneity remained high even after excluding one study with extreme variance, suggesting that other clinical and methodological factors such as patient age and hydrocephalus etiology may be more dominant in explaining the differences than the risk of bias of a single study. Overall, the sensitivity analysis showed that the meta-analysis results were robust, with no substantial change in the direction or significance of effect after excluding certain studies.

Publication bias

Publication bias was assessed using a funnel plot for the primary outcome of procedural success. The funnel plot showed the distribution of studies around the pooled effect line (log risk ratio). Among the 10 studies analyzed, the distribution of points was relatively symmetric without any marked asymmetric clustering on one side of the plot. This indicates no strong evidence of publication bias for this outcome. Although one or two small studies appeared slightly deviant, the overall distribution remained within acceptable limits of symmetry. It can

therefore be concluded that the risk of publication bias in this meta-analysis was low and did not significantly affect the overall effect estimate of ETV+CPC compared with VP shunt (Figure 7).

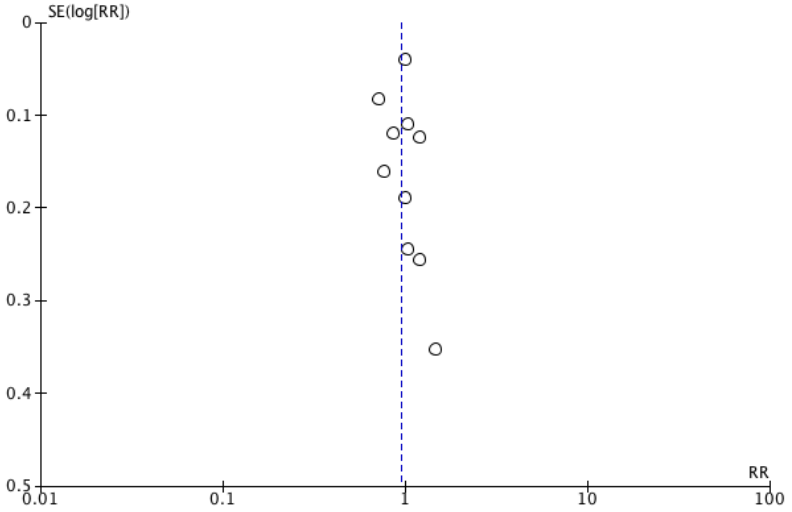


Figure 7. Funnel plot of the procedural success outcome between ETV+CPC and VP shunt.

DISCUSSION

This meta-analysis synthesized 10 studies comparing ETV+CPC with VP shunt in pediatric hydrocephalus, assessing effectiveness, durability, and safety while identifying factors influencing outcomes. Overall, procedural success did not differ significantly between the two, whereas ETV+CPC showed advantages in complication profile and potentially greater durability; mortality was comparable, and sensitivity and subgroup analyses reinforced the findings, with high heterogeneity as the principal limitation.[21,22] The pooled risk ratio for procedural success was 0.96 (95% CI 0.84–1.09; p = 0.52; I^2 = 66%) an almost neutral effect indicating that ETV+CPC can match VP shunt when patients are appropriately selected, consistent with Minta et al. (RR = 0.84; 95% CI 0.80–0.90; I^2 = 0%; p = 0.93), and with reports that optimally performed CPC allows long-term ETV+CPC success to compete with shunting.[21,23] Heterogeneity in success likely reflected varying definitions of success, follow-up duration, patient age, etiology, and operator experience; very young infants (<6 months) were more prone to ETV failure from stoma closure or progressive subarachnoid obstruction, and in aqueductal stenosis in infants <24 months an OR of 1.74 (95% CI 0.85–3.58) tended to favor VPS.[24]

For revision, the RR was 1.30 (95% CI 0.72–2.33; p = 0.38) with very high heterogeneity (I^2 = 86%), reflecting inconsistent definitions of revision and follow-up; shunt revision is generally due to mechanical malfunction, obstruction, or infection, whereas ETV+CPC failure arises from re-obstruction or suboptimal stoma formation. Intraoperative stoma evaluation, adequate CPC technique, and early postoperative surveillance (6–12 months, when most ETV failures occur) mitigate this risk, and if the stoma remains patent beyond the critical phase the durability of ETV can surpass that of VPS.[9,25] The most striking finding was a significant reduction in complications with ETV+CPC (RR = 0.42; 95% CI 0.21–0.83; p = 0.02; I^2 = 49%) an approximately 58% lower risk than VPS consistent with Minta et al. (2023), who reported post-procedural complications of 4.6% for ETV versus 27.1% for VPS (RR = 0.76; 95% CI 0.42–1.38; p = 0.04), and with recent meta-analyses showing lower infection and mechanical complications for ETV. This advantage stems from eliminating the implanted device avoiding infection, migration, catheter obstruction, and over-drainage and is a highly meaningful benefit where access to surgical escalation is limited.[21,26,27]

Time-to-failure analysis favored ETV+CPC with a mean difference of 3.62 months (95% CI 0.12–6.45; p = 0.04), though heterogeneity was very high (I^2 = 98%); Warf et al. similarly observed that ETV failures occur early but durability is good once the stoma remains patent. Because only some studies reported TTF in comparable formats (days, weeks, months converted), interpretation requires caution, and future studies should present Kaplan–Meier survival curves and hazard ratios to strengthen durability meta-analyses.[3,7,12,15] Post-procedural mortality did not differ significantly (RR = 1.01; 95% CI 0.55–1.83; p = 0.98; I^2 = 0%), indicating very low and comparable medium-term risk, in line with recent meta-analyses. As mortality events are rare and analyses often underpowered, the absence of a clear difference supports basing intervention decisions on efficacy, complications, and durability rather than survival.[20,28,29]

Subgroup analyses indicated that the advantage of ETV+CPC was more evident in patients aged ≥6 months and with obstructive etiology, consistent with literature showing better ETV success in aqueductal stenosis than in post-infectious or non-obstructive cases; Warf et al. and Alali et al. reported higher success in infants ≥6 months (presumably reflecting subarachnoid maturity and stoma patency), whereas post-infectious or intraventricular-hemorrhage etiologies had higher failure rates from adhesions and impaired CSF absorption supporting stratification by age and etiology.[7,20,24] Accordingly, several recommendations follow: ETV+CPC may be a first-line intervention in children with obstructive etiology and age ≥6 months, particularly where shunt-revision access

is limited; adequate CPC technique and intraoperative stoma evaluation are essential; close monitoring and early intervention are crucial in the first 6–12 months; developing countries should strengthen endoscopic training and build systematic local registries; and future research should be prospective or randomized, reporting survival curves, hazard ratios, and stratification by age and etiology.[30,31]

From an economic perspective, ETV+CPC requires a higher initial investment (endoscopic equipment, a visualization system, and a cauterization device) but a lower long-term operational cost, as it avoids an implanted device and carries fewer complications, whereas VP shunt is cheaper initially and more accessible but incurs significant long-term costs from revision, infection, and periodic replacement with reported failure rates of 30–40% within the first two years and about 80% of children requiring at least one lifetime revision.[9,25] VP shunt failure also tends to be more severe, potentially sudden and fatal with total obstruction or systemic infection, whereas ETV+CPC failure is usually more progressive and detectable earlier, making ETV+CPC a more sustainable option under limited re-intervention access when performed by trained operators with appropriate patient selection.[30,32] A significant implementation gap remains: ETV+CPC requires specialized neuroendoscopic expertise and equipment (endoscopes, cauterization systems, intraoperative navigation) not evenly available across facilities in Indonesia, particularly in resource-limited areas, whereas VP shunt is more widely performed. Overall, ETV+CPC is a comparable or even superior alternative to VP shunt in safety and durability especially in children aged ≥6 months with an obstructive etiology though operator competence, equipment availability, and service-system readiness remain the primary determinants in procedure selection.[7,21]

Limitations

Several limitations must be considered in interpreting this meta-analysis. Most studies were retrospective and non-randomized, and were therefore susceptible to selection bias and confounding. Outcome definitions (success, revision, complications) were not uniform across studies, complicating data harmonization. Only a small proportion of studies provided time-to-failure data in an analyzable format, so durability could not be concluded firmly. Mortality events were relatively rare, so the mortality analysis was statistically underpowered. High heterogeneity in several outcomes cautions that interpretation should be undertaken carefully and in context.

CONCLUSION

Based on the pooled results of 10 observational studies, there was no significant difference in procedural success or mortality between ETV+CPC and VP shunt in children with hydrocephalus, but ETV+CPC showed significantly fewer complications (particularly infection and mechanical failure) and a significantly longer time to failure, indicating a better safety profile and long-term durability; revision rates were comparable, although ETV tended to fail early while VPS more often required long-term revision. Procedure selection should therefore be tailored to patient characteristics especially age and etiology with ETV+CPC a reasonable first choice in patients with obstructive hydrocephalus aged ≥6 months given its lower complication rate and greater durability, even though the difference in success was not statistically significant. However, ETV+CPC cannot always be applied widely, particularly in LMICs, owing to limited endoscopic facilities, scarcity of choroid plexus cauterization devices, and the need for a specially trained pediatric neurosurgical consultant; enhanced neurosurgical training, including basic-to-advanced endoscopy, together with government and institutional support for endoscopic equipment and evidence-based clinical protocols that account for age, etiology, and facility capacity, is needed to enable safer and broader application in resource-limited centers.

BIBLIOGRAPHY

1. Enslin JMN, Dewan MC, Warf BC, Baticulon RE. Hydrocephalus in low and middle-income countries progress and challenges. Neurol India. 2021;69(Suppl 2):S292-S297.
2. Baticulon RE, Dewan MC. Endoscopic third ventriculostomy and choroid plexus coagulation in infants: current concepts and illustrative cases. Neurol India. 2021;69(Suppl 2):S514-S519.
3. Ferris E, Kulkarni AV, Constantini S. The etiology of pediatric hydrocephalus across Asia: a systematic review and meta-analysis. J Neurosurg Pediatr. 2024;33(4):323-333.
4. Albalkhi I, Shah V, Kulkarni AV. Morbidity and etiology-based success rate of combined endoscopic ventriculostomy and choroid plexus cauterization: a systematic review and meta-analysis of 1918 infants. Neurosurg Rev. 2023;46(1):180.
5. Ariyati NF, Gunawan PPI, Sustini FF. Profil klinis dan faktor risiko mortalitas pada anak dengan hidrosefalus di RSUD dr. Soetomo Surabaya. Sari Pediatri. 2021;22(6):364-370.
6. Zhang M, Hu X, Wang L. A review of cerebrospinal fluid circulation and the pathogenesis of congenital hydrocephalus. Neurochem Res. 2024;49(5):1123-1136.
7. Warf BC, Weber DS, Day EL, et al. Endoscopic third ventriculostomy with choroid plexus cauterization: predictors of long-term success and comparison with shunt placement for primary treatment of infant hydrocephalus. J Neurosurg Pediatr. 2023;32(2):201-213. doi:10.3171/2023.4.PEDS2310
8. Thavarajasingam SG, Williams MA, Hakim R, Marmarou A. Clinical predictors of shunt response in the diagnosis and treatment of idiopathic normal pressure hydrocephalus: a systematic review and meta-analysis. Acta Neurochir (Wien). 2021;163:2641-2672.
9. Dahlan RH, Ompusunggu SE. Risk factors for shunt failure in pediatric patients with hydrocephalus: a systematic literature review. J Kedokteran. 2024;10(1):17-27.

10. Anele CO, Kanu OO, Okorie ON, Olaniyi JA. Hydrocephalus management challenges in a low-income country: a review article. J West Afr Coll Surg. 2021;11(3):29-34.
11. Ikwuegbuenyi CA, Adepoju F, Yusuf T. Implementing evidence-based interventions for managing pediatric hydrocephalus: a systematic review protocol. J Surg Protoc Res Methodol. 2023;2023(1):snac026.
12. Adebayo BO, Kanu OO, Bankole OB, Ojo OA, Adetunmbi B, Morgan E. Early outcome of endoscopic third ventriculostomy with choroid plexus cauterization versus ventriculoperitoneal shunt as primary treatment of hydrocephalus in children with myelomeningocele: a prospective cohort study. Oper Neurosurg. 2021;21(6):461-466. doi:10.1093/ons/opab314
13. Kulkarni AV, Schiff SJ, Mbabazi-Kabachelor E, et al. Endoscopic treatment versus shunting for infant hydrocephalus in Uganda. N Engl J Med. 2017;377(25):2456-2464. doi:10.1056/NEJMoa1707568
14. Navaei AA, Hanaei S, Habibi Z, et al. Controlled trial to compare therapeutic efficacy of endoscopic third ventriculostomy plus choroid plexus cauterization with ventriculoperitoneal shunt in infants with obstructive hydrocephalus. Asian J Neurosurg. 2018;13(4):1042-1047. doi:10.4103/ajns.AJNS_63_17
15. Izah J, Haizel-Cobbina J, Zhao S, et al. Treatment of hydrocephalus following fetal repair of myelomeningocele: comparing endoscopic third ventriculostomy with choroid plexus cauterization to ventricular shunting. J Neurosurg Pediatr. 2024;34(3):207-215. doi:10.3171/2024.5.PEDS24171
16. Cairo SB, Agyei J, Nyavandu K, Rothstein DH, Kalisya LM. Neurosurgical management of hydrocephalus by a general surgeon in an extremely low resource setting: initial experience in North Kivu province of Eastern Democratic Republic of Congo. Pediatr Surg Int. 2018;34(4):467-473. doi:10.1007/s00383-018-4238-0
17. Chimaliro S, Hara C, Kamalo P. 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 Neurochir (Wien). 2023;165(1):61-69. doi:10.1007/s00701-022-05392-7
18. Pindrik J, Riva-Cambrin J, Kulkarni AV, et al. Surgical resource utilization after initial treatment of infant hydrocephalus: comparing ETV, early experience of ETV with choroid plexus cauterization, and shunt insertion in the Hydrocephalus Clinical Research Network. J Neurosurg Pediatr. 2020;26(4):337-345. doi:10.3171/2020.4.PEDS19632
19. Dewan MC, Lim J, Gannon SR, et al. Comparison of hydrocephalus metrics between infants successfully treated with endoscopic third ventriculostomy with choroid plexus cauterization and those treated with a ventriculoperitoneal shunt: a multicenter matched-cohort analysis. J Neurosurg Pediatr. 2018;21(4):339-345. doi:10.3171/2017.10.PEDS17421
20. Alali A, Alkabouni W, Aretz V, et al. One year mortality after pediatric hydrocephalus treatment: a comparative analysis of endoscopic third ventriculostomy and ventriculoperitoneal shunt. Front Surg. 2025;12:1538899. doi:10.3389/fsurg.2025.1538899
21. Minta KJ, Kannan S, Kaliaperumal C. Outcomes of endoscopic third ventriculostomy (ETV) and ventriculoperitoneal shunt (VPS) in the treatment of paediatric hydrocephalus: systematic review and meta-analysis. Childs Nerv Syst. 2024;40(4):1045-1052.
22. Pande A, Lamba N, Mammi M, Gebrehiwet P, Trenary A, Doucette J, et al. Endoscopic third ventriculostomy versus ventriculoperitoneal shunt in pediatric and adult populations: a systematic review and meta-analysis. Neurosurg Rev. 2021;44:1227-1241.
23. Warf BC. The impact of combined endoscopic third ventriculostomy and choroid plexus cauterization on the management of pediatric hydrocephalus in developing countries. World Neurosurg. 2013;79(2 Suppl):S23.e13-S23.e15. doi:10.1016/j.wneu.2011.02.012
24. Rosyidi RM, Priyanto B, Januarman, Wahyudi, Rozikin, Wardhana D. Endoscopic third ventriculostomy vs ventriculoperitoneal shunt in aqueductal stenosis: a systematic review and meta-analysis. Interdiscip Neurosurg. 2024:101951.
25. Limwattananon P, Kitkhuandee A. Ventriculoperitoneal shunt failure in pediatric patients: an analysis of a national hospitalization database in Thailand. J Neurosurg Pediatr. 2021;28(2):128-138.
26. Jesuyajolu DA, Ibrahim Y, Adeleye AO. Endoscopic third ventriculostomy versus ventriculoperitoneal shunt insertion for the management of pediatric hydrocephalus in African centers—a systematic review and meta-analysis. Surg Neurol Int. 2022;13:467.
27. Akbar H, Patel P, Sethi A. Efficacy and safety of endoscopic third ventriculostomy versus ventriculoperitoneal shunting for the treatment of hydrocephalus: a meta-analysis. Clin Neurol. 2024;8(2):19-25.
28. Pasqualotto E, Schmidt PHS, Ferreira ROM, Chavez MP, da Silva FFS. Endoscopic third ventriculostomy versus ventriculoperitoneal shunt in patients with obstructive hydrocephalus: an updated systematic review and meta-analysis. Asian J Neurosurg. 2023;18(3):468-475. doi:10.1055/s-0043-1774308
29. Tully HM, Doherty D, Wainwright M. Mortality in pediatric hydrocephalus. Dev Med Child Neurol. 2022;64(1):112-117.
30. Park YS. Treatment strategies and challenges to avoid cerebrospinal fluid shunting for pediatric hydrocephalus. Neurol Med Chir (Tokyo). 2022;62(9):416-430.
31. Panagopoulos D, Stranjalis G, Gavra M, Boviatsis E, Korfias S, Karydakis P. Current trends in the treatment of pediatric hydrocephalus: a narrative review centered on the indications, safety, efficacy, and long-term outcomes of available treatment modalities. Children (Basel). 2024;11(11):1334.
32. Vadset TA, Kulkarni AV, Schiff SJ. Improving infant hydrocephalus outcomes in Uganda: a longitudinal prospective study protocol for predicting developmental outcomes and identifying patients at risk for early treatment failure after ETV/CPC. Metabolites. 2022;12(1):78.