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Selection of Surgical Interventions in Pediatric Hydrocephalus : A Literature Review

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ABSTRACT

Introduction: Hydrocephalus is a condition in which the flow of cerebrospinal fluid is disturbed due to an imbalance between production and reabsorption or because there are obstacles along its distribution channel. The most common surgical intervention and standard strategy for treating hydrocephalus in recent years has been the placement of a shunt, particularly a ventriculoperitoneal shunt (VP-Shunt). In addition to shunt placement, endoscopic third ventriculostomy (ETV) and choroid plexus coagulation (CPC) are currently being performed simultaneously, considering that the combination of the two procedures is sufficient to provide maximum results and can even reduce the risk of failure.

Method: The method of literature review is used in this study**.**The method chosen is preferred reporting items for systematic reviews and meta-analyses (PRISMA), which involves selecting the characteristics of literature through electronic media with database searches through the PubMed and Google Scholar sites. Patients diagnosed with hydrocephalus, both communicative and noncommunicative, with an age of 18 years; surgical intervention with a Vp-shunt; EVT with or without CPC; and a 3-month follow-up were the inclusion criteria.

Result: There were 1,251 samples included in the 10 articles in this study, 7 of these articles had samples with non-communicable hydrocephalus, with the most common etiologies being post-infection and hemorrhage. The selected interventions, both Vp-Shunt and ETV with or without CPC, have a high percentage of success rates, with an average age of intervention in this study of 6 months.

Conclusion: The choice of intervention in cases of hydrocephalus should be based on patient characteristics. Installation of a shunt, ETV, or ETV/CPC may 1et he first choice based on the etiology of the hydrocephalus, the patient's age, and a risk assessment that takes into account the complications that may arise from the selected procedure.

Keywords: Hydrocephalus, pediatric, review

1. Introduction

Hydrocephalus is a case which is a challenge for various fields including pediatrics, neurology and especially neurosurgery. Hydrocephalus can occur due to the flow of cerebrospinal fluid which experiences an imbalance between production and reabsorption as well as obstacles along its distribution channels.[1]

The prevalence of these cases is quite high, based on studies assessing epidemiology and incidence from 34 countries and 6 continents representing WHO authority areas, approximately 400,000 new cases have been reported almost all over the world with the highest incidence in Africa and Latin America with 145-316 cases/100,000 births. [2]

In Indonesia cases of hydrocephalus reach 0.2-4 incidence/1000 births. Based on data from RSUD dr. Soetomo Surabaya from January 2014 to September 2016 it was reported that 17.97% of pediatric hydrocephalus patients experienced mortality.[3] Hydrocephalus is a clinical condition that can be prevented by modifying risk factors such as meningitis vaccination and good antenatal care, especially in cases of pediatric hydrocephalus.[4]

The most common surgical intervention that has become the standard treatment strategy for hydrocephalus in the last few decades is the installation of a ventriculoperitoneal shunt (VP-Shunt).[5] Even though VP-shunt provides significant results in pediatric hydrocephalus patients, mortality and morbidity rates are still high, such as infection, obstruction, can even result in slit ventricle syndrome and excessive drainage so that it requires further surgical or medical intervention. The emergence of the EVT procedure, which has been popularized in recent years due to improved endoscopic visualization and lower complication rates, has begun to become an alternative in hydrocephalus, especially in obstructive cases.[7] In addition to its success rate in evacuating cerebrospinal fluid properly, ETV can also cause potential complications such as intraoperative bleeding and cranial nerve palsies. [6][8]

Endoscopic Third Ventriculostomy (ETV) and Choroid Plexus Coagulation (CPC) in practice are often performed simultaneously, because the combination of these two procedures can provide maximum results and can reduce the risk of failure compared to just choosing EVT alone. The combination of EVT/CPC has shown success in several studies of pediatric hydrocephalus and reduces the likelihood of further shunt placement. Despite the advances in neurosurgery, the selection of the most efficient procedure for surgical intervention in pediatric hydrocephalus is still controversial, given the failure and complication rates of each procedure. Therefore, a comprehensive assessment was carried out from several available studies to determine which is the best intervention that can be chosen based on the type and clinical condition, especially in pediatric hydrocephalus. [9]

2. Method

Research uses library research methods or literature review by searching, collecting, evaluating, reviewing, and critically analyzing ideas, knowledge, and findings written in academic-oriented literature with the aim of theoretically concluding and applying topics related to the choice of surgical intervention and outcome in pediatric hydrocephalus. A systematic literature review approach is used in this literature review.

Preferred Reporting Items for Systematic Review and Meta-Analyses (PRISMA) is the method used in this article.Identification, screening, eligibility, and meeting the criteria are the four stages that must be completed. The selection of literature characteristics was carried out through electronic media by searching databases through the PubMed and Google Scholar sites. A literature search strategy using keywords: pediatric hydrocephalus, ventriculoperitoneal shunt, endoscopy third ventriculostomy, choroid plexus coagulation, which were published from January 2020 to June 2022 using English. After obtaining several articles related to keywords, checking is carried out to ensure that there are no similar articles. Next, ascertain whether the article is feasible for analysis and meets the inclusion criteria in this study.

The inclusion criteria used were patients diagnosed with communicating or non-communicating hydrocephalus, aged 18 years, who underwent surgical intervention with a Vp-shunt, EVT with or without CPC, and were followed up for at least 3 months. The exclusion criteria were hydrocephalus in children caused by brain injury, hydrocephalus without surgical intervention, and no post-operative follow-up. The study was conducted using the literature review method, and the data found during the search will be evaluated based on questions that match the quality assessment criteria (quality assessment) as follows:

1. What is the maximum timeframe for journals published in the last 3 years (2020–2022)?
2. Does the journal use English?
3. Is the journal a type of original research article (not a review article)?
4. Is the journal available in PDF format?
5. Is the journal available in full text and as a download?
6. Does the journal theme have relevance to research with the theme of selecting surgical interventions and outcomes in pediatric hydrocephalus?

Journal analysis in the study was carried out by reading the abstract and full-text of the journal carefully, then making a conclusion based on the written content according to the research objectives and the results or research findings. All the data collected was then analyzed by assessing the similarities and differences, the advantages and disadvantages, and then discussed in depth to draw a research conclusion.

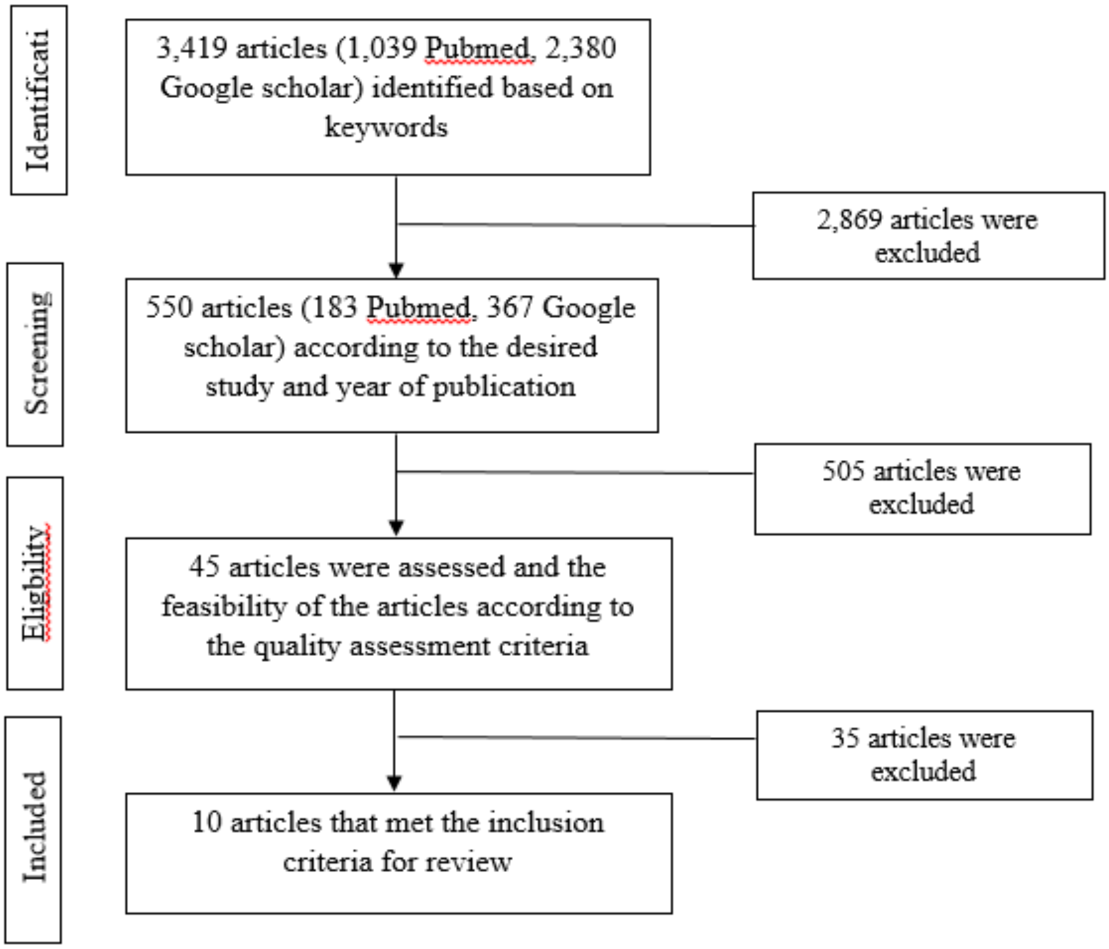

Fig. 1 Research Methods

3. Results

Based on a literature search with the keyword "surgical intervention for obstructive hydrocephalus and communications in pediatrics," 3,419 articles were found, of which 1,039 came from PubMed and 2,380 from Google Scholar; filtered based on year, 550 articles (183 from PubMed and 367 from Google Scholar) were published. From 2020 until now, after an assessment of feasibility and conformity with the research of this study was carried out, 45 studies were obtained, and a literature review was carried out based on a quality assessment, so that 10 literatures were taken, which would be reviewed according to the inclusion criteria of this study.

In this study, there are several actions performed as a surgical intervention option for hydrocephalus. Of the 1,251 samples included in the 10 articles in this study, there were 350 ETV actions, 696 Vp-Shunt, 12 EVD, 139 Ommaya reservoirs, ETV/CPC 73, ETV/Shunt 1, Vp-Shunt revision 45, and ETV/CPC revision 1.

It appears that shunt installation and EVT are the most widely used in the management of hydrocephalus in children. The etiology of hydrocephalus in this study was quite diverse; the study conducted by Singh and Rebecca had the highest percentage of etiology in cases of post-infection hydrocephalus, namely 35% and 65%. While the research conducted by Holwerda, Kenichi, and Peter was dominated by causes of intraventricular hemorrhage with a percentage of 42%, 30%, and 45.3%, respectively, This is different from the study by Say Riva and Angela Ros, where the majority of the samples experienced hydrocephalus caused by 32.5% tectal tumors and 36.7% midbrain tumors. Rahman et al found that congenital hydrocephalus was responsible for 58.8% of cases in their study.

Table 1 Characteristic Data Based on Literature Search

		Singh R, et al (n = 117)	**Holwerda, et al (n = 349)**	**Rebecca, et al (n = 378)**	**Rahman, et al (n = 34)**	**Angela, et al (n = 40)**	**Coulter, et al (n = 158)**	**Adebayo, et al (n = 45)**	**Usami, et al (n = 63)**	**Spazzapan, et al (n = 64)**	**Cambrin, et al (n = 60)**
Hydrocephalus	Communicans	35%	30%	**66%**	14.7%	25%	5.7%	**100%**	**100%**	15.8%	27.3%
	Non-communicans	**65%**	**70%**	34%	**85.3%**	**75%**	**94.3%**	-	-	**84.2%**	**72.7%**
Etiology	Infection	**35%**	5%	**65%**	14.7%	-	5.7%	-	0.05%	1.5%	1.7%
	Hemorrhage	-	**42%**	-	-	-	5.7%	**-**	0.08%	**51.5%**	1.7%
	Neoplasma	32.5%	6%	0.08%	23.5%	**52.5%**	-	-	0.05%	32.7%	**65%**
	Congenital	17.1%	22%	11.1%	**58.8%**	7.5%	-	**100%**	0.1%	3%	25.1
	Others	15.4%	25%	23.82%	3%	30%	**88,6%**	-	**99.72%**	10.9%	6.5%
Age of Subject		≤ 12 yo	≤ 2 yo	< 18 yo	2.5 mo – 14 yo	5-18 yo	< 24 mo	< 2 yo	< 15 yo	≤ 15 yo	5-17 yo
Intervention Time		6 mo – ≤ 2 yo	< 6 mo	< 6 mo	6 mo - ≤ 2 yo	6 mo - < 2 yo	< 6 mo	< 6 mo	6 mo - ≤ 2 yo	6 mo - ≤ 2 yo	> 2 yo
Intervention Types	Vp-shunt	**90.3%**	**40.4%**	**86.5%**	-	-	27.3%	48.9%	**71.4%**	**54.7%**	21.7 %
	ETV	7%	16.9%	-	**100%**	**100%**	**72.7%**	-	28.6%	45.3%	**78.3 %**
	ETV+CPC	-	-	13.5%	-	-	-	**51.1%**	-	-	-
	Others	2.7%	42.7%	-	-	-	-	-	-	-	-
Mean Length of Follow-up		7.2 mo	24 mo	3 mo	50.47 mo	64.5 mo	35 mo	6 mo	6 yo	27,5 mo	6 mo
Complication	Shunt	22.3%	**49.7%**	19,9%	-	-	20.9%	4.5%	**40%**	**54%**	**7.7%**
	ETV	**25%**	47.4%	**21,5%**	**50%**	**27,5%**	**33%**	**8.6%**	33%	10.3%	4.3%
	Others	0.1%	51 %	-	-	-	-	-	-	-	
Outcome	Success rate	39.5%	49.8%	**79.1%**	**79%**	**72,5%**	**70.3%**	**60.9%**	**61.9%**	**54.6%**	**95%**
	Failure rate	**48.3**	**50.2%**	11,7	21%	27,5%	29.7%	39.1%	39.1%	45.4%	5%
	Mortality	12.2%	-	7%	-	-	0.6%	-	-	-	-

The average age for intervention in this study was 6 months, in the study conducted by Singh R., 43.5% of surgical procedures were performed on children aged 1-6 months, this is also in accordance with the study conducted by Holwerda, which had a percentage of 44%, but 50% of them underwent revision of both the shunt and ETV

4. Discussion

In a study conducted by Sukriti Das et al., a prospective experimental method was used by researchers to assess how the outcome of the selected surgical intervention in draining CSF in pediatric patients with hydrocephalus resulted in the conclusion that ETV is superior to VP-Shunt due to the low incidence of infection and the possibility of minor re-operation.[10]

The choice of surgical action taken is actually adjusted to the etiology and age of the patient, which also need to be considered. Hydrocephalus is broadly divided into communicating and non-communicating/obstructive; in communication, what happens is a decrease in the absorption of CSF flow so that it is unable to catch up with the speed of production, and as a result, CSF accumulates in the intraventricular. In non-communicating or obstructive conditions, an obstruction in the CSF flow path to the subarachnoid space causes CSF flow to become obstructed.[11]

There are several actions that can drain CSF again; one of the actions that is currently an option for neurosurgeons is the installation of shunts and ETV with or without CPC. The type of shunt that is most often used is the venrticuloperitoneal (VP) shunt, although shunt flow can also be carried out in the subgaleal, atrial cavity, and pleural cavity. [12] However, shunt installation often causes failure and complications. One of the causes of shunt failure is obstruction, which occurs due to excessive drainage and causes debris to enter the proximal catheter. In addition to obstruction in the proximal part of the catheter, occlusion in the distal part can also occur due to the accumulation of blood and protein fluids, which cause the accumulation of debris. In addition, exposure to a shunt can also cause infection, which will cause changes in the function of the skin as a protector. The pressure of the shunt on the skin over time will also cause ischemia and infection.[13]

Endoscopic Third Ventriculostomy (ETV) in the last decade has become quite popular considering that endoscopic visualization is currently getting better and the complication rate caused in several studies is said to be lower than shunt installation. ETV is an invasive surgical procedure in which penetration is made into the floor of the third ventricle using a ventriculoscope and assisted by imaging guidance. The aim of this procedure is to divert the flow of CSF to a site of physiological reabsorption. This is accomplished by establishing free flow of CSF from the third ventricle into the interpenduncular cistern system and then into the cortical subarachnoid space, where it is absorbed by the arachnoid villi. CSF flow is thus diverted elsewhere in an attempt to avoid obstruction and reduce intracranial pressure.[14]

The choice of ETV action is usually carried out in the obstructive type of hydrocephalus, according to the working mechanism of the procedure, but several studies explain that ETV can also be an option in hydrocephalus of the communicating type. One of the studies that explains this is by Kenichi Usami et al., where ETV in children with hydrocephalus is quite relevant if it is done, because in children aged 2 years, CSF is absorbed by the capillaries of the ependymal ventricles because the arachnoid villi are still immature. An increase in intraventricular pulsation causes a decrease in CSF absorption through the blood vessels, causing a gradual accumulation of CSF, this causes a decrease in intracranial venous volume, this acts as a buffer for pulsative pressure or compensation so that the pulsative pressure remains balanced. However, the decrease in venous volume results in a decrease in CSF flow through the capillaries, so the accumulation of CSF increases, which causes a vicious circle.

Therefore, the ETV procedure is carried out with the aim of ending the cycle by creating a pathway to the cisternal system so that pulsative pressure can be restrained, and the ETV procedure accompanied by CPC also contributes to reducing pulsative pressure in the choroid plexus so that production and absorption can be balanced. Communication with ETV action, either with or without CPC, fails in cases of hydrocephalus, possibly due to failure to achieve differences in pulsative pressure or because CSF absorption function in the intraventricular glymphatic system is lost due to bleeding or infection.[15]

There were several causes of hydrocephalus in this study, according to Holwerda et al., intracranial bleeding (42% of cases) and congenital abnormalities (22% of cases) were the most common etiologies. The average operation is performed at the age of 1-6 months, and for the interventions performed, 50% of them have to re-operate, but it is not clear what revision of the intervention was carried out. [16] While Rebecca A. Reynolds et al. found that 65% of the samples had hydrocephalus with an infectious etiology, the remaining 35% had non-post-inflammatory hydrocephalus, with the highest percentage being ideopathic congenital 29%. The majority of the samples in this study had intervention procedures within the previous year.[17] Congenital hydrocephalus was also the most common etiology in the study conducted by Rahman et al, with a percentage of 58.9% of the total sample, and 79% experienced success after surgery.[18]

The four most common etiologies that cause hydrocephalus in the sample population, according to the 10 studies reviewed in this study, are intraventricular hemorrhage, postinflammatory hydrocephalus, tumors, and congenital hydrocephalus.This is in accordance with the results of the Hydrocephalus Clinical Research Network (HCRN), where post-hemorrhagic hydrocephalus from prematurity is one of the most common causes and the most frequent etiology of pediatric hydrocephalus and has been the focus of a number of studies at HCRN since the center was established in 2006.[19]

Considering that it affects the outcome of the actions we are about to perform, it is crucial to pay attention to the time of the intervention. In this study, the average surgical procedure was performed within 6 months; this was explained in the research by Singh R (2021), Holwerda (2020), Rebecca (2020), Ian C (2020), and Kenichi (2021) with varying success rates, but the majority of these studies suggest ETV with or without CPC compared to Vp-Shunt considering the risk of shunt failure and the high incidence of infection. In contrast to research published by HCRN, which compared the success rate of ETV/CPC with ETV and VPShunt in infants aged 2 years, The main result of this study is that the success rate at six months of age for ETV-CPC is 36%, while the success rate at six months of age for shunt installation is 76%. However, for the ETV-CPC group, infants who were older, with smaller ventricles, and with more choroid plexus CPC measures tended to have higher success rates. The success rate of ETV-CPC differs depending on the age at which the baby is being treated and the type of hydrocephalus that you have. Infants with myelomeningocele or other types of non-posthemorrhagic hydrocephalus, as well as infants with aqueductal stenosis (> 1 month of corrected age), may be the best candidates for ETV-CPC. [20]

Both with the VP-Shunt and the ETV installations, there were a number of issues in this investigation. The closure of the ventriculostomy stoma, the existence of a second membrane, and the development of granulations around the stoma are the causal factors for failure in ETV.[18] The main causes of ETV failure are complex hydrocephalus and prior shunting activity, but there are other potential risk factors as well. By determining the actual cause of hydrocephalus before surgery, the success rate of ETV can be increased and unnecessary surgery can be avoided. Stoma closure as a result of a local inflammatory response is typically the most frequent mechanism of failure, and these occurrences are also connected to the underlying pathophysiology. Risks from the ETV's output include hematoma, infection, subdural hygroma, and CSF leak. ETV has freed individuals with hydrocephalus from the shunt's difficulties and dependency.[18] In contrast, the shunt procedure's failure can be attributed to shunt infection and catheter proximal and distal end occlusion. Therefore. Using the BR Chhabra shunt, which has a significantly lower risk of infection than a regular shunt in general, is one of the alternatives advised in one of the articles included in this study. Installing a shunt given antibiotics can also be an alternative.[1] With more surgical experience as the operator, there is also a higher risk of complications. Considering the uncommon but real hazards of the operation, doctors must carefully pick patients who have a good chance of recovery. It can also be carried out with only a brief hospital stay and postoperative stay in the intensive care unit, which has a significant effect on the child's survival.[18]

5. Conclusion

Based on our study, from the total of 58 patients, most of the patients were boys (69%). The most The choice of intervention in cases of hydrocephalus should be based on patient characteristics. Installation of a shunt, ETV, or ETV/CPC may be the first choice based on the etiology of the hydrocephalus, the patient's age, and a risk assessment that takes into account the complications that may arise from the selected procedure.

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Conflict of Interest

The authors declare no conflicts of interest in preparing this article.

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