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Role of Bangladesh Medical College Hospital (B.M.C.H) Protocol in Achieving Zero Shunt Infection in Paediatric Hydrocephalus

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Abstract:

Ventriculoperitoneal shunt infection is one of the most dreadful complications of shunt surgery. Though topical, intravenous, and intraventricular antibiotics have been used; the infection rate is still high. It is a retrospective cohort study from Jan 2018 to Dec 2022 in Bangladesh Medical College, performed by a single Neurosurgeon. **Objective:** To see the effectiveness of the B.M.C.H protocol of shunt surgery in minimizing shunt infection. **Method:** 83 pediatric Ventriculo Peritoneal shunt cases were selected, who met the inclusion criteria. They were divided into 2 groups. One group had an Ommaya reservoir with or without endoscopic third ventriculostomy (failed) and was subject to cerebrospinal fluid aspiration for a considerable period followed by a shunt. The other group had conventional shunt (non-Ommaya) surgery. **Results:** The overall infection rate in our hospital in shunt surgery is 3.6%. Among the non-Ommaya or conventional shunt group, it reached 7.1%, while among the Ommaya group, there was not a single shunt infection in the follow-up period. 47% of babies came from the poorest population of the country. There was no significant relationship found between infection with a history of previous infection, per operative use of an endoscope, early age, or preterm birth. Follow up period was between 6 to 18 months. **Conclusions:** In a non-specialized hospital in a third-world country with limited neurosurgical capacity, following B.M.C.H. protocol, we found the babies who had Ommaya reservoir and underwent regular cerebrospinal fluid aspiration for a period of time before Ventriculo peritoneal shunt surgery were infection free in the long and short time follow up.

Keywords: *Ommaya group, Non-Ommaya group, B.M.C.H protocol, Shunt infection.*

Introduction

Ventriculoperitoneal shunt infection is one of the commonest infections in the pediatric age group. As the surgery is designed to save lives but its complications are often life-threatening. Specially in third-world countries, when babies face these calamities, their parents or families won't bring them to the hospital again for follow-up or the next level of treatment. For these complications, the public gets the wrong message about the credibility of the surgery. Complications can arise from mechanical blockage, wrong placement of catheter tip, and infections. Moreover, the peritoneal end of the catheter can perforate the bowel, cause obstruction and pseudocyst formation (Wu, 2007; Chung, 2009; Athanasakis, 2011; Braga, 2009; Misaki, 2010)

Shunt infection remains a significant source of morbidity even in the developed country with a

perioperative infection rate of 1% -15%. Babies are specially vulnerable due to immaturity of the immune system, and skin colonization and they are prone to sepsis (Choux, 1992; Drake, 1998; Enger 2003; Reddy, 2012). Low birth weight babies with thin skin and scanty subcutaneous fat make them prone to injury during passing the shunt introducer.

In third-world countries like Bangladesh, shunt infection causes an immense financial burden to the family as there is no health insurance coverage. There are very few studies regarding shunt infection, however, it reached 24.2% in a center (Choudhury, 2022). In this grave situation for infants, ETV is the treatment of choice. But, unfortunately in all cases of hydrocephalus, ETV is not a good option and there is an early failure. Even for babies younger than 6 months with obstructive hydrocephalus, the success rate was only 12.5% (Ahmed, 2013). In some cases, they present with severe forms of cardiac and respiratory problems. In those cases, they are denied general anesthesia and even if they get it, it becomes impossible for the parents to avail of NICU/PICU. In this scenario, we thought the implantation of an Ommaya reservoir after ETV through the same port could buy some time to gain weight in the event of ETV failure. Even for babies, who are unfit for general anesthesia or any acute reason, an Ommaya implantation under local anesthesia can be immensely helpful. Regular aseptic aspiration of CSF in intervals results in reduced ICP, delaying shunt, and better cosmetic outcomes. There are cases where babies with infected shunts come with extreme malnutrition. In those cases, shunt removal is followed by EVD, and after that Ommaya reservoir implantation is extremely beneficial (Hamid, 2023). Babies with Ommaya reservoir undergo VPS when they gain sufficient weight.

For the babies, who come after 6 months with an average weight, we do ETV but if there is a thick third ventricular floor/ distorted anatomy/ flow is not adequate and cisternal scaring we do VPS in the same sitting.

But in cases of non-obstructive hydrocephalus, we don't do an endoscopy and go for the conventional shunt (Hamid, 2023).

Methodology

Patients

It is a retrospective cohort study of 83 cases of pediatric VPS surgery who met the inclusion criteria. The place of the study was Bangladesh Medical College Hospital during the period between January 2018 to December 2022.

Inclusion criteria

1. Babies of shunt surgery who had completed at least 6 months of follow-up.
2. Babies who left for shunt-related complications to other centers but all of those complications were noted in our database.
3. Age less than <=18 years.

Exclusion criteria

1. Babies who died in the immediate postoperative period.
2. Post-tumoral hydrocephalic cases.
3. Insufficient data

The pediatric patients who were operated on in B.M.C Hospital during the period from January 2018 to December 2022 and met the inclusion criteria, their details were collected from the database. The follow-up schedule was 2 months, 6 months, 12 months, and 18 months following surgery and then yearly. During discharge from the hospital, all the parents were sufficiently made to understand the signs and symptoms of shunt complications. They were provided with a leaflet containing pictures of complications and a "Help Line" number for any questions or clarification.

Grouping

Ommaya Group

According to B.M.C.H protocol, all the infants of Hydrocephalus are treated with ETV and Ommaya Reservoir implantation. Of them, some had stoma closure after a period of time. In some cases, ETV was abandoned per operative findings. There was also a number of patients who were not fit for general anesthesia due to pulmonary and cardiac anomalies, they were given only the Ommaya reservoir under local anesthesia. All these 3 categories of patients

underwent regular CSF aspiration at certain intervals and Acetazolamide was added to decrease production of CSF.

Non-Ommaya/ Conventional Group

The babies had Conventional shunts. For many of them, an endoscope was used to see the chances of good ETV and do fenestration if needed.

For children of both groups data like age, body weight (Indian Academy of Paediatric growth chart), socio-economic status, gestational age at delivery, etiology, mode of presentation, per operative use of the endoscope, duration of surgery, use of Y shunt, interval time between surgery and infection, follow up period, etc. were noted. If babies left our hospital for higher centers the type of shunt complications were noted in the database.

In all cases, Surgiwear medium pressure Chhabra shunt was used, while only 3 babies had the Medtronic delta valve with reservoir.

Shunt infection was defined when a baby presented with any of the following (Alkosha, 2022; McGirt, 2003)

1. Presence of pathological microorganisms in CSF culture or shunt system.

2. Unexplained fever with neurological deterioration/inflammation/ discharge/ skin loss along the shunt tube/abdominal symptoms, presence of pseudocyst may or may not be associated with the culture-positive specimen.

Results

To see the independent association between the two groups, the data was analyzed by using SPSS software (Ver. 26).

During the study period from January 2018 to December 2022, a total of 83 eligible cases were included in the study, on whom 84 shunts were inserted. The infection rate was 0% among the Ommaya and 7.1% among the non-Ommaya group.

Ommaya Group

Among the Ommaya group children, there were 41 patients. 58.5% were boys and the rest were girls (41.5%). Half of the patient population belonged to the low socio-economic group. 70.7% had Ommaya ± ETV at or before the age of 1 month. During this time, 75.6% had body weight below normal for their age, and sex. This Ommaya group of patients underwent CSF aspiration at regular intervals. 63.4% of patients had their VPS at the age between 3 to 6 months. During this time 85.4% gained average body weight. The majority of this Ommaya group had congenital and meningomyelocele type of hydrocephalus. During shunt surgery, for most of the patients, an endoscope was not used. 46.3% took more than 1 hour to complete surgery. 12.2% of patients had a history of previous Ommaya infection and revision. In subsequent shunt surgery, no one had a shunt infection. 4.9% of babies initially presented with shunt infection and were later treated with EVD and then Ommaya. None of these patients had shown shunt infection in short and longtime follow-ups. 87.8% of patients in this group had a history of failed/abandoned ETV. 56.1% of this group completed their follow-up more than 18 months after surgery. 7.3% of this group returned with mechanical blockage/ fracture of hardware and they left for higher centers. Infection in this group was 0%.

Non-Ommaya/ Conventional Group

This group constituted 42 patients. 66.7% were male and the rest were female (33.3%). The majority 26.2%, had their shunts between 6 to 12 months of age. 85.7% of patients had normal body weight for age and sex, during surgery. 57.1% had congenital hydrocephalus followed by post-infective variety (31%). In 50% of cases, simultaneous endoscopy was used either for ETV or fenestration. 76.2% of patients had surgery with a duration of more than 1 hour. 4.8% of patients had a history of previous shunt revision. 57.1% completed follow-ups more than 18 months and above. Infection in this group was 7.1%.

Table 1. Distribution of Results by OM and Non-OM Groups

Variable Name	OM Group (n=41) Percent	Non-OM Group (n=42) Percent	Both (All) (n=83) Percent
Sex			
Boys	58.5	66.7	62.7
Girls	41.5	33.3	37.3
Socio-economic			
Poor	51.2	42.9	47.0
Middle	34.1	45.2	39.8
Upper	14.6	11.9	13.3
Age of Ommaya ±ETV			
1 month	70.7		70.7
1-3 months	14.6		14.6
3-6 months	9.8		9.8
6-12 months	2.4		2.4
13 months and above	2.4		2.4
Weight during Ommaya			
Below normal	75.6		75.6
Normal	22.0		22.0
Overweight	2.4		2.4
Age of shunt			
< 1month	0.0	4.8	2.4
1-3 months	14.6	9.5	12.0
>3-6 months	63.4	19.0	41.0
>6-12 months	17.1	26.2	21.7
>12-24 months	2.4	9.5	6.0
>24-36 months	0.0	16.7	8.4
>36 months	0.0	2.4	1.2
>48-60 months	0.0	2.4	1.2
>60-72 months	2.4	7.1	4.8
>96 months & above	0.0	2.4	1.2
Weight during shunt			
Bellow normal	4.9	11.9	8.4
Normal	85.4	85.7	85.5
Obese	9.8	2.4	6.0
Etiology			
Congenital	41.5	57.1	49.4
Post infective	24.4	31.0	27.7
Meningomyelocele	26.8	9.5	18.1
Post haemorrhagic	7.3	2.4	4.8
Endoscopy			
Yes	7.3	50.0	28.9
No	92.7	50.0	71.1
Duration of surgery			
<1 Hour	53.7	23.8	38.6
>1 Hour	46.3	76.2	61.4
Organism detected C/S			
Yes	0.0	2.4	1.2
No	0.0	4.8	2.4
Not applicable	100.0	92.9	96.4
Infection interval			
<2 months	0.0	2.4	1.2
2-6 months	0.0	4.8	2.4

Not applicable	100.0	92.9	96.4
H/O shunt revision			
Yes	4.9	4.8	4.8
No	95.1	95.2	95.2
H/O shunt infection			
Yes	4.9	4.8	4.8
No	95.1	95.2	95.2
H/O Ommaya infection			
Yes	12.2	0.0	6.0
No	85.4	0.0	43.4
Not applicable	2.4	100..	50.6
H/O Ommaya revision			
Yes	12.2	0.0	6.0
No	85.4	0.0	43.4
Not applicable	2.4	100.00	50.6
Mode of presentation			
Hydrocephalus/failed ETV	87.8	76.2	81.9
Mechanical obstruction	7.3	19.0	13.3
Infection	2.4	2.4	2.4
Mechanical+ infection	2.4	2.4	2.4
Year of surgery			
2018	24.4	31.0	27.7
2019	29.3	38.1	33.7
2020	0.0	2.4	1.2
2021	29.3	14.3	21.7
2022	17.1	14.3	15.7
Follow up			
6 month after surgery	9.8	11.9	10.8
>6-12 months after surgery	19.5	23.8	21.7
>12-18 months after surgery	14.6	7.1	10.8
>18 months & above	56.1	57.1	56.6
Shunt infection in BMC			
Yes	0.0	7.1	3.6
No	100.0	92.9	96.4

Gestational age less than 36 weeks was defined as a pre-term baby. We never did a conventional shunt on pre-term and low birth weight patients.

Infection that occurred within 2 months of surgery was defined as "early" and later was classified as "late".

There is no dedicated operation theater for Neurosurgery. The same theater is also shared by the Department of Urology and colorectal surgery. The elective procedure schedule is once a week only. We don't have a paediatric neurosurgery wing but on principle, we keep babies as the first case of the day.

Drawbacks of The Protocol

1. Babies belonging to the Ommaya group have to come for regular aspiration. It is difficult for the parents and has its own expenses.
2. Dedicated personnel with patience and empathy, strict asepsis during CSF aspiration is mandatory for the neurosurgical team.
3. Sometimes, educated parents are trained to aspirate CSF, arranging this training and regular follow-up of parents is quite challenging.

Discussion

Though VPS is one of the commonest and most preferred procedures with its recent improvement and newer protocol for insertion, the 1-year failure rate was reported to be high as 40%, Hazem. M. Alk had found an infection rate

of 11.5%, mostly occurring as early infection, while the etiology was not significant (Alkosha, 2022)

We found an overall infection rate of 3.6%. All the infections occurred in the Non-Ommaya group (7.1%) and 0% in the Ommaya group. But the number was not sufficient to do any significance test.

Mathew J McGart found an infection rate of 11% and most of them occurred within 19 days of insertion. Pre-term babies were more susceptible to infection. The use of an intraoperative endoscope was associated with a higher rate of infection either due to an increase in surgery time or contamination of the endoscope (McGirt, 2003).

We never did any VPS on pre-term babies. Those babies had Ommaya ± ETV and there was not a single case of infection. Though some had their Ommaya infected, it was managed properly.

Kunal P et al in 2022 did a study showing findings on 593 VPS done on 302 patients in 11 years. They followed a standard surgical technique including topical and intra-ventricular vancomycin in Children's Hospital of Oakland. They found infection incidents of 3.2 %. Most of the infections occurred very early within 2 months of surgery. For babies, less than 6 months of age, the post-operative leak had a significant relationship with infection (Raygor, 2020).

We used topical Vancomycin also and there was not a single case of post-operative leak.

Reza Akbar Basitan et al examined age as a risk factor. They studied 98 pediatric patients from 2017 to 2019. They found patients aged >3-6 had a significantly increased risk of shunt infection. The infection rate was 15.1% (Bastian, 2022). They explained that the newborn had passive immunity. One of the IgG is IgG anti-Sa which gives protection against Staphylococcal infection (Nadaf, 2016).

However, we discouraged early shunt surgery in infants for low birth weight and immaturity of skin.

A study conducted by Amir Erps et al at the Tel Aviv University on 1570 shunt-related procedures. They found the annual infection rate at 4.2%. They found that the most significant factor for shunt infection was shunt revision and age above 5 was found to be protective (Erps, 2018).

Joon Kee Lee et al had a study on 333 shunts in 6 years, 10.5% of shunts were infected, infection appeared within 6 days to 8 months after insertion, age below 1 year and post haemorrhagic hydrocephalus was significant. The infection rate for a reinserted shunt was higher than the first inserted shunt. 17.2% of the reinserted case had prior shunt infection while 12.1% had mechanical obstruction (Lee, 2012).

In our study, we collected the history of previous infections and revision in both groups. Patients who were treated with Ommaya prior to shunting showed no subsequent infection. But the number was not enough to see any significance.

Shunt infection in African countries is higher; 9% - 32%, Naomi Ochieng et al found in a study with 53 VPS infections. Among them, 68% of babies were less than 6 months of age and 79% of infections were within 2 months of insertion. 51% of infection was caused by Staphylococcus species, while in 40% of cases, the culprit was gram-negative bacteria. These gram-negative bacteria were multi-drug resistant but sensitivity to Meropenem was outstanding (Ochieng', 2015).

We found 2.4% of our patients under the study, who had an early infection. The culture of the hardware yielded no growth of organisms. They left B.M.C for a higher center. Rest of the infected cases (4.8%) presented within 2 to 6 months. One of them yielded the growth of Klebsiella which was sensitive to Colomycin. We removed the shunt and did EVD. He was treated with intravenous Colomycin and it was also used for ventricular wash. But there was scanty drainage. So, we discharged him with an Ommaya reservoir and are currently on follow-up. The explanation could be gram-negative bacteria already destroyed the choroid plexus (Ochieng', 2015).

A patient who had PIH had abandoned ETV followed by VPS. She presented after 3 months with erythema and surgical site infection. She was treated with shunt removal, EVD. The culture was negative but gram staining showed fungus. After 10 days we removed EVD and put a VPS on the opposite side. Unfortunately, after 1 month she had the same problem and left for higher centers.

Sukriti Das et al had done a prospective study on VPS complications after the first surgery at Bangabandhu Sheikh Mujib Medical University, Bangladesh in 2019-20. They checked out complications within one month of pediatric VPS. Among the complications 8.33% shunt infection within 1 month of insertion. (Sukriti, 2021).

Kaiser Haroon et al published literature regarding signs and symptoms of shunt infection including all age groups of the same institution for the period of 2008-2010. The majority of the patients were in the pediatric age group and overall shunt infection was 23.33% (Kaiser, 2016).

There is a study regarding shunt infection conducted during 2015-18 in Combined Military Hospital, Dhaka, Bangladesh. The shunt infection rate was found 24.2%. Prolonged operation time, low socioeconomic conditions, and emergency surgeries were key factors of infection (Choudhury, 2022).

In the BMCH protocol, all paediatric hydrocephalus that is less than 6 months are initially treated by endoscopic procedure + Ommaya reservoir implantation. Ommaya is also used for babies more than 6 months of age who come with shunt infection and malnutrition. In the cases, initially we give external ventricular drainage followed by Ommaya Reservoir to buy time for babies to regain weight. Strict adherence to the protocol could not be maintained due to socioeconomic conditions and parent's non-compliance to the treatment procedure.

Limitations of the Study

1. Retrospective, single hospital, single neurosurgeon.
2. Patient volume is not so high.

Conclusions

Shunt infection causes morbidity, mortality, and huge financial problem for the family. Here the Ommaya group shows a good possibility to mitigate this problem. We don't know why the Ommaya group remained infection free and like to learn more from the prospective, multicentric study of the B.M.C.H protocol.

Declaration of competing interests

The author declares she has no competing interests.

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Abbreviations

ETV: Endoscopic Third Ventriculostomy

VPS: Ventriculo Peritoneal Shunt

B.M.C.H: Bangladesh Medical College Hospital

NICU: Neonatal intensive care unit

PICU: Pediatric intensive care unit

PIH: Post infective hydrocephalus

References

Alkosha, H. M., Mohammed, M. I. R., El Shokhaiby, U. M., & Amen, M. M. (2022). A Proposed Protective Protocol Predicting Reduction of Shunt Infection. *World neurosurgery*, *164*, e1049–e1057. https://doi.org/10.1016/j.wneu.2022.05.090

Athanasakis, E. (2011). Post operative complications of ventriculoperitoneal shunt in hydrocephalic pediatric patients-nursing care. *International Journal of Caring Sciences , 4(2),* 66-71

Bastian, R. A., Pramusinto, H., Basuki, E., & Marianne, M. (2022). Ventriculoperitoneal Shunt Infection: A Study about Age as a Risk Factor in Hydrocephalus Pediatrics. *Open Access Macedonian Journal of Medical Sciences*, *10*(B), 314–319. https://doi.org/10.3889/oamjms.2022.8251

Braga, M.H.V., Carvalho, G.T.C.D., Brandao, R.A.C.S., lima, F.B.F.D., & Costav, B.S. (2009). Early shunt complications in 46 children with hydrocephalus. *Arquivos de neuropsiquiatria, 67,* 273-277. https://doi.org/10.1590/S0004-282X2009000200019

Choudhury, A.M., Salek, M.A.A, Faisal, H. & Islam, M.A. (2022). VentriculoPeritoneal Shunt Infection; Three Years Experience in Combined Military Hospital, Dhaka. *JAFMC Bangladesh*, *18*(1), 16-18

Choux, M., Genitori, L., Lang, D., & Lena, G. (1992). Shunt implantation: reducing the incidence of shunt infection. *Journal of neurosurgery*, *77*(6), 875–880. https://doi.org/10.3171/jns.1992.77.6.0875

Chung. J. J., Yu, J.S., Kim, J. H., Nam, S. J., & Kim, M. J. (2009). Intraabdominal complications secondary to Ventriculo peritoneal shunts: CT findings and review of the literature. *American Journal of Roentgenology, 193(5),1311-1317.*

Drake, J. M., Kestle, J. R., Milner, R., Cinalli, G., Boop, F., Piatt, J., Jr, Haines, S., Schiff, S. J., Cochrane, D. D., Steinbok, P., & MacNeil, N. (1998). Randomized trial of cerebrospinal fluid shunt valve design in pediatric hydrocephalus. *Neurosurgery*, *43*(2), 294–305. https://doi.org/10.1097/00006123-199808000-00068

Enger, P. Ø., Svendsen, F., & Wester, K. (2003). CSF shunt infections in children: experiences from a population-based study. *Acta neurochirurgica*, *145*(4), 243–248. https://doi.org/10.1007/s00701-002-1068-5

Erps, A., Roth, J., Constantini, S., Lerner-Geva, L., & Grisaru-Soen, G. (2018). Risk factors and epidemiology of pediatric ventriculoperitoneal shunt infection. *Pediatrics international : official journal of the Japan Pediatric Society*, *60*(12), 1056–1061. https://doi.org/10.1111/ped.13709

Hamid, R., Gomes, V. C., Huda, N., Khan, A. R., Chowdhury, M., & Azam, I. (2023). Role of Ommaya Reservoir in Pediatric Hydrocephalus: Experience in Bangladesh Medical College Hospital from 2019-2021. *Mymensingh medical journal : MMJ*, *32*(2), 510–519.

Kaiser H, Tania T, Mokhlesur R, & Kanak KB. (2016). Signs and Symptoms of Early VP Shunt Infection in a Tertiary Hospital. *Bang J. Neurosurgery,* 5(2), 41-43

Lee, J. K., Seok, J. Y., Lee, J. H., Choi, E. H., Phi, J. H., Kim, S. K., Wang, K. C., & Lee, H. J. (2012). Incidence and risk factors of ventriculoperitoneal shunt infections in children: a study of 333 consecutive shunts in 6 years. *Journal of Korean medical science*, *27*(12), 1563–1568. https://doi.org/10.3346/jkms.2012.27.12.1563

McGirt, M. J., Zaas, A., Fuchs, H. E., George, T. M., Kaye, K., & Sexton, D. J. (2003). Risk factors for pediatric ventriculoperitoneal shunt infection and predictors of infectious pathogens. *Clinical infectious diseases : an official publication of the Infectious Diseases Society of America*, *36*(7), 858–862. https://doi.org/10.1086/368191

Misaki, K., Uchiyama, N., Hayashi, Y., & Hamada,J.I.(2010). Intracerebral Hemorrhage Secondary to Ventriculoperitoneal shunt insertion-Four Case Reports-. *Neurologia medico – chirugica,*76-79. https://doi.org/10.2176/nmc.50.76

Nadaf, M. I., Lima, L., Stranieri, I., Takano, O. A., Carneiro-Sampaio, M., & Palmeira, P. (2016).

Passive acquisition of anti-Staphylococcus aureus antibodies by newborns via transplacental transfer and breastfeeding, regardless of maternal colonization. *Clinics (Sao Paulo, Brazil)*, *71*(12), 687–694. https://doi.org/10.6061/clinics/2016(12)02

Ochieng', N., Okechi, H., Ferson, S., & Albright, A. L. (2015). Bacteria causing ventriculoperitoneal shunt infections in a Kenyan population. *Journal of neurosurgery. Pediatrics*, *15*(2), 150–155. https://doi.org/10.3171/2014.10.PEDS14178

Reddy, G. K., Bollam, P., & Caldito, G. (2012). Ventriculoperitoneal shunt surgery and the risk of shunt infection in patients with hydrocephalus: long-term single institution experience. *World neurosurgery*, *78*(1-2), 155–163. https://doi.org/10.1016/j.wneu.2011.10.034

Raygor, K. P., Oh, T., Hwang, J. Y., Phelps, R. R. L., Ghoussaini, K., Wong, P., Silvers, R., Ostling, L. R., & Sun, P. P. (2020). Ventriculoperitoneal shunt infection rates using a standard surgical technique, including topical and intraventricular vancomycin: the Children's Hospital Oakland experience. *Journal of neurosurgery. Pediatrics*, *26*(5), 504–512. https://doi.org/10.3171/2020.4.PEDS209

Sukriti D, Asifur R, Haradhan DN, Rathin H, & Dipankar G. (2021) Thirty days complications of pediatric hydrocephalus following ventriculoperitoneal shunt surgery. *International Journal of Neurology Research,* 3(1), 1-5

Wu. Y., Green, N. L., Wrensch, M. R., Zhao, S., & Gupta, N. (2007). Ventriculoperitoneal shunt complications in California: 1990 to 2000. *Neurosurgery, 61(3),* 557-563.

Zohdi, A. Z., El Damaty, A. M., Aly, K. B., & El Refaee, E. A. (2013). Success rate of endoscopic third ventriculostomy in infants below six months of age with congenital obstructive hydrocephalus (a preliminary study of eight cases). *Asian journal of neurosurgery*, *8*(3), 147–152. https://doi.org/10.4103/1793-5482.121686

Appendix 1

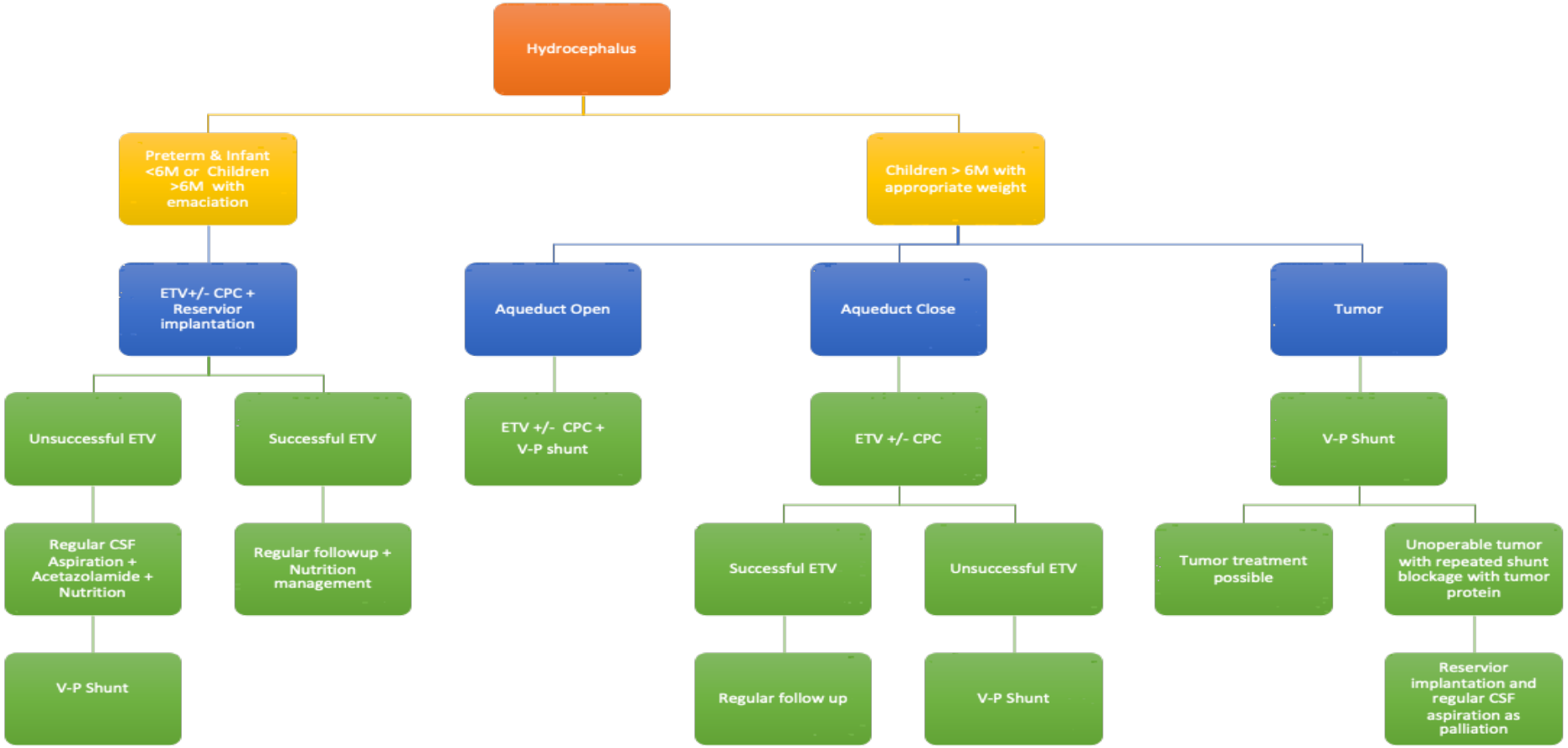

Diagram 1. B.M.C.H Protocol for Pediatric Hydrocephalus

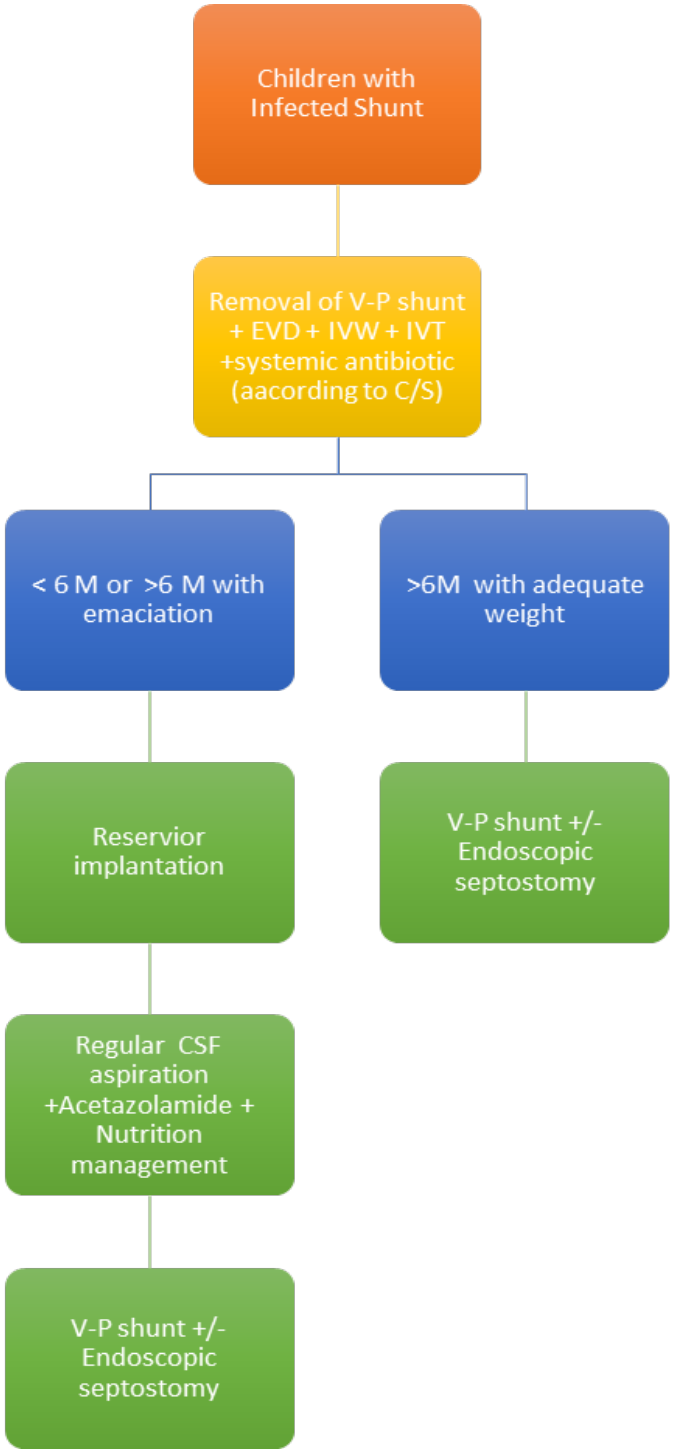

Diagram 2. BMCH Protocol for Children with Infected Shunt