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ORIGINAL ARTICLE

Comparison of Accuracy of Ventricular Catheter Tip Placement by Conventional Free-Hand Method and Electromagnetic Neuronavigation Guided Ventriculoperitoneal Shunt Surgery

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ABSTRACT

Background: *Ventriculoperitoneal (V-P) shunt surgery has a long history and is one of the most established neurosurgeries around the world. The purpose of V-P shunt surgery is to divert an accumulation of cerebrospinal fluid (CSF) from the cerebral ventricles to the abdominal cavity. Accurate placement of ventricular catheter is depended on both proper insertion trajectory and proper catheter tip positioning.* ***Objective:*** *To compare the proportion of optimal ventricular catheter tip placement by two different ventriculoperitoneal shunt procedures.* ***Methods & Materials:*** *This cross-sectional observational study was conducted in Department of Neurosurgery, National Institute of Neurosciences & Hospital, Dhaka. 60 participants with Hydrocephalus, diagnosed by CT scan of brain and who underwent ventriculoperitoneal shunt surgery, were studied. All participants were divided into 2 groups by random lottery system.* ***Results:*** *Total 60 participants were included in our study among them 0-1year of age group showed maximum participants of 66.67%. 10(16.67%) belong to 1-5 years' age group among them 6(20%) participants from Group B and 4(13.33%) participants from Group A. 8.33% belongs to 6-10 years age group among them 6.67%from Group B, 10% from Group A. Study shows the majority of study participants 40 (66.67%) were male where 20 (33.33%) were female. male female ratio was 2:1.* ***Conclusions:*** *Frameless navigation is a valuable tool to optimize the trajectory and final position of shunt catheter in the ventricle. Mechanical malfunction and infection are the most significant problems associated with shunts for the treatment of hydrocephalus.*

Keywords: *Hydrocephalus, Ventriculoperitoneal Shunt, Ventricular Catheter Placement, Catheter Tip Positioning.*

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INTRUDUCTION

Hydrocephalus is a pathological accumulation of cerebrospinal fluid (CSF) in the ventricular system due to abnormal production, flow, or absorption of CSF [1]. The buildup of CSF increases the intracranial pressure, producing a variety of neurological defects concurrent with ventriculomegaly [2]. Arising from multiple congenital, acquired and idiopathic pathologies, hydrocephalus can ultimately lead to brain damage in the compressed tissues if left untreated [3,4]. Hydrocephalus is primarily treated using a shunt system or Endoscopic third ventriculostomy (ETV). In shunt system draining the excess CSF from the cerebral ventricles into another region of the body where it can be absorbed. The peritoneal cavity remains the preferred drainage site in both pediatric and adult populations, accessed using a ventriculoperitoneal (V-P) shunt [5]. Ventriculoperitoneal shunt surgery is a well-established neurosurgery all over the world. The purpose of V-P shunt surgery is to divert an accumulation of cerebrospinal fluid (CSF) from the cerebral ventricles to the abdominal cavity. V-P shunts are comprised of a proximal inflow catheter, reservoir, valve mechanism, and a distal outflow catheter. The proximal catheter generally lies in the trigone of the lateral ventricle. A retro-auricular unidirectional valve follows the reservoir and is responsible for controlling the flow of CSF into the distal catheter. The distal catheter then travels subcutaneously from the valve into the right upper abdominal quadrant where the excess CSF can freely drain into the peritoneal cavity [4,6]. There is evidence that accurate placement of the ventricular catheter is significantly related to shunt survival. Accurate placement of ventricular catheter is depended on both proper insertion trajectory and proper catheter tip positioning. A ventricular catheter tip surrounded by CSF decreased the risk of shunt failure to one fifth, whereas a catheter tip touching the brain decreased the risk to one-third compared with a catheter tip surrounded by brain tissue [7]. So recently, many studies have validated accuracy in V-P shunt with the development of frameless neuronavigation in the field of neurosurgery [8]. Thus, the chief concern when inserting a V-P shunt should be the precise placement of the ventricular catheter. The standard technique of ventricular catheter placement depends on anatomic landmarks; however, this may not be satisfactory to consistently ensure optimal positioning of the ventricular catheter. The optimal position of the catheter tip was focused to reduce potential occlusion of proximal catheter by ventricular parenchyma or choroidal tissues [9]. According to the results of the previous studies, various methods have been suggested to improve the accuracy of catheter tip position. Described a method of calculating catheter length based on bony landmarks on skull radiographs and a shunt placement by free-hand passage using simple stereotactic guidance and palpable surface anatomy [8]. Ascertained the catheter position using X-ray imaging by filling the catheter with contrast medium V-P shunts are often complicated by malfunction, predominantly with proximal catheter obstruction despite improved surgical equipment and operative skill [10]. Electromagnetic Neuronavigation systems have been developed for image-guided neurosurgery to aid in the accurate resection of brain tumors [11,12]. Basic principles of navigated surgery are to see the tip of a pointer in an image space. A relationship between the device space and the image space has to be established [13]. Accurate placement of ventricular catheter is related with both proper insertion trajectory and proper catheter tip positioning. So recently, many studies have validated accuracy in ventriculoperitoneal shunt with the development of frameless neuronavigation in the field of neurosurgery [14].

METHODS & MATERIALS

Cross sectional observational study. Department of Neurosurgery National Institute of Neurosciences & Hospital. Dhaka, Bangladesh. The study was carried out from June, 2022 to February, 2024. Participants diagnosed as Hydrocephalus by means of CT scan of brain, who underwent ventriculoperitoneal shunt surgery, at department of Neurosurgery, National Institute of Neurosciences & Hospital. Total sample size 60 participants Group A 30 Participants who have been operated by conventional freehand method. Group B 30 Participants who have received electromagnetic neuronavigation guided system.

Inclusion criteria

Patients with Hydrocephalus, diagnosed by CT scan of brain, whom V-P shunt was done. Ageless than18 years

Exclusion criteria

Recurrent case. Distorted ventricular anatomy (extreme HCP, hydranencephaly)

Data collection methods

A ventriculoperitoneal shunt was done in the operating room under general anesthesia. All the procedures were performed by experienced neurosurgeons. In the conventional freehand method, skin incision and trepanation of the cranium were done by using anatomical landmark Keens point. Ventricular catheter length was determined based on surgeon's measurement using brain computed tomography (CT) imaging. In the electromagnetic neuronavigation system, preoperative data acquisition in 3 planes was obtained by CT scan. The ventricular catheter was placed over the guiding stylet to identify the location of anatomy. The final outcome was measured by CT scan taken on first post-operative day.

Data processing and analysis

The numerical data obtained from the study was analyzed and significance of differences was estimated by using statistical methods. The Statistical Package for Social Sciences (SPSS) version 25.0 software was used for data analysis. Categorical variables were expressed as absolute number & percentages and compared through the proportion test and the chi-square ($\chi 2$) test or Fisher's exact test when appropriate. Continuous variables were expressed as the mean, median, standard deviation and was compared through the Fisher's exact test when appropriate.

A p-value of less than 0.05 was considered to constitute a statistically significant difference. Latest Harvard style of referencing by Open University was followed throughout the thesis work.

Ethical considerations

Ethical clearance for the study was taken from the Department of Neurosurgery and Ethical Review committee, National Institute of Neuroscience & Hospital, Dhaka, Bangladesh. Written informed consent was taken from the patients and their legal guardians. Every step of the study followed the recommendations according to Helsinki Declaration in 2000.

Procedure for maintaining confidentiality

For safeguarding confidentiality and protecting anonymity, each of the participants was given and special ID number, which was used for further communication, if needed. All types of data were protected confidentially and would not disclose to any third party except ethical committee of Institutional Review Board (IRB). These data would never be used in any commercial purpose.

Quality assurance strategy

This study was conducted under direct supervision of the guide and maximum quality was assured at all steps. Detailed history and Clinical examinations were carried out by the principal investigator. The radiological analysis was performed by the principal investigator and expert opinion was taken when needed. Here exclusion –inclusion criteria were strictly followed. All data was collected with the direct supervision by the guide. Quality was maintained by periodic discussion with professional assistance and supervisor. Data was checked randomly by the guide. Statistical analysis was done with the help of an expert stuff. It was an unbiased study. There was no violation of human rights and Helsinky declaration was followed.

RESULTS

Majority (66.67%) of participants belong to the age Group of 0-1 year followed by 2-5 years of 16.67%. Both 6-10 and 11-15 had the same contribution of 8.33% (Table I).

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Table I: Age distribution of participants (*n*=60)

Age (years)	Group-A No/ (%)	Group-B No/ (%)	Total N (%) No/ (%)
0-1 year	20(66.67%)	20(66.67%)	40(66.67%)
2-5years	4(13.33%)	6(20%)	10(16.67%)
6-10years	3(10%)	2(6.67%)	5(8.33%)
11-15years	3(10%)	2(6.67 %)	5(8.33%)
Total	30(50%)	30(50%)	60(100%)

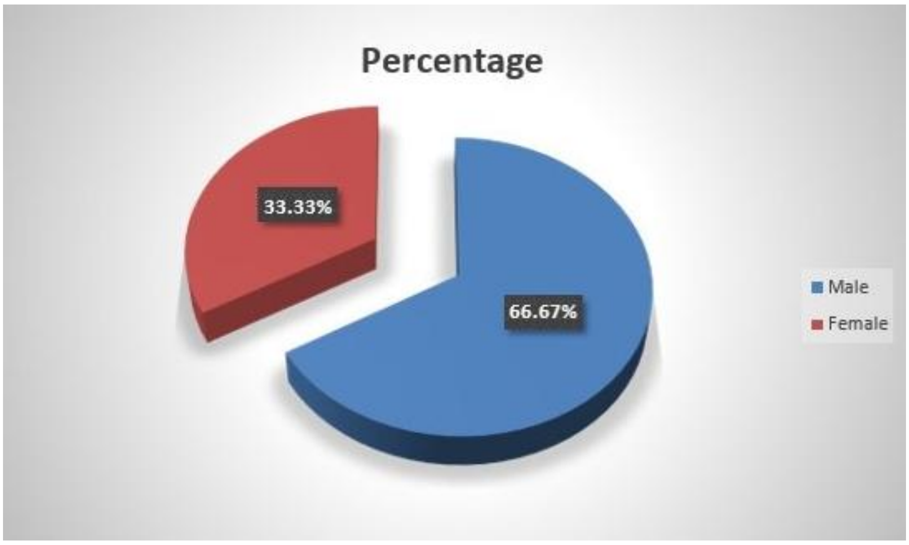

Figure 1: Sex distribution of the participants (*n*=60)

Figure 1 shows the majority of study participants 40 (66.67%) were male where 20 (33.33%) were female. male female ratio was 2:1.

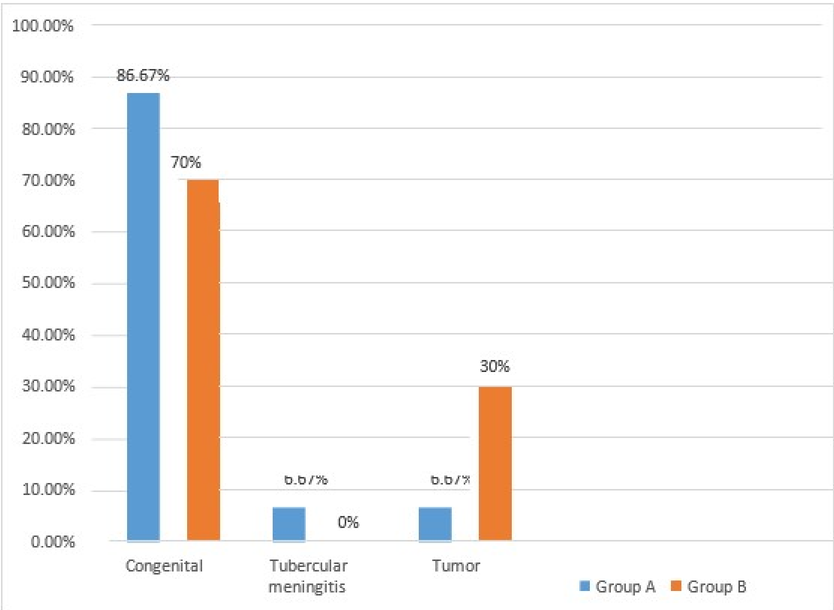

Figure 2: Distribution of hydrocephalus etiology among participants (*n*=60)

Figure 2 Shows etiology distribution among participants. Congenital hydrocephalus is the most common one 47(78.33%) followed by tumor 11 (18.33%) and tubercular meningitis shows 3.33% contribution.

Comparison of conventional and neuronavigation method by measuring the bi-frontal span. In conventional method Grade I shows mean bi-fontal span of 24mm, Grade of II 37.46mm, and Grade III of 42.16mm. In neuronavigation method Grade I had mean of 25.26mm, Grade II and Grade III had of 35.75 mm and 47.67 mm respectively (*Table II*).

Table II: Comparison between conventional and neuronavigation method from bi-frontal span calculation(*n*=60)

Method	Grade I Mean +/SD	Grade II Mean+/SD	Grade III Mean+/SD
Conventional Group-A	24 ±6.92	37.46 ±9.81	42.16 ±7.09
Neuronavigation Group-B	25.26±6.79	36.83 ±7.14	47.67 ±6.67

Comparison between two Groups about catheter tip placement. From both of Groups 18 participants had Grade I placement, 28 had Grade II and 14 had Grade III. Among 18 participants had Grade I placement Group A had only 16.67% participants and 83.33% Group B participants. Among 28 Grade II participants 53.57% from Group A and 46.42% from Group B. 85.71% participants from Group A had Grade III placement where 14.28% from Group B (*Table III*).

Table III: Comparison of grading of catheter tip placement between two Groups (*n*=60)

Grade	Group A No/ (%)	Group B No/ (%)	Total No/ (%)	P value
Grade I	3(16.67%)	15(83.33%)	18(100%)	
Grade II	15(53.57%)	13(46.42%)	28(100%)	
Grade III	12(85.71%)	2(14.28%)	14(100%)	0.03

DISCUSSION

This study included 60 participants of hydrocephalus with the etiology of congenital, tubercular meningitis and tumor fulfilling the inclusion criteria. Then the participants were divided into two Groups as Group A and Group B. The Group A participants had conventional free hand placement of V-P shunt and Group B had neuronavigation guided shunt placement. Post-operative CT scan was done to see the catheter placement and grading was done and comparison between Group A and Group B was done. Total 60 participants were included in present study among them 0-1year of age Groups had 40(66.67%) participants. Study conducted by Salvador al found 77% patients with hydrocephalus below one-year age [15]. Age Group of 2-5 years had 10(16.67%) participants followed by 6-10 and 11-18 years had 8.33% participants respectively. Which denotes with increasing age incidence rate of hydrocephalus decreases. In present study 66.67% were male and 33.33% were female. Male predominance was found with a ratio of 2:1, Badawy et al found 63.3% male participants of hydrocephalus close to this study [16]. The incidence of congenital hydrocephalus has been estimated at 0.5 cases per 1000 live births and the incidence of neonatal hydrocephalus has been estimated at 3-5 cases per 1000 live births, with a male predominance [17]. Etiological distribution showed among the study participants congenital hydrocephalus was the most common one 47(78.33%). De Oliveira et al found 50% of the babies with tumor had hydrocephalus that's not similar to our study, because incidence rate varies from country to country [18]. Salvador et al found 32% babies had congenital anomaly for hydrocephalus and 2.5% with tumor etiology similar to our study [15]. Rajshekhar V found 87%–90% of children with tubercular meningitis had hydrocephalus [19]. Where in our study 3.33% tubercular meningitis babies had hydrocephalus. This difference is due to previous study was done only on TBM babies but we select babies with different etiologies. We compare both of the method by measuring bi-frontal span in study population. It showed mean diameter in Grade I of study population of conventional method is 24 mm. Wilson et al had minimum targeted accuracy of 24.6mm in conventional method, that's similar to our study [20]. In neuronavigation method mean diameter in Grade I study population is 25.26, comparable to Wilson et al had minimal targeted accuracy of Grade I study population was 25.8. This is simillar to our study [20]. We found only 16.67% Grade I placement by conventional method but Ji-Hoon Lee et al found 83.1% Grade I success rate at free hand or conventional method, dissimilar to our study [21]. Because, participants Group included here ranges from 1-15 years but they include all ages of patients. With better neuro imaging tools, skill of surgeons and more facilities they found this much success rate. Toma et al noted accurate freehand placement occurring in between 39.9% and 97.8% of procedures [22]. Ji-Hoon Lee et al. reported 42.5% of freehand placements in the ipsilateral frontal horn of the lateral ventricle [21]. Hsieh et al. reported (64.3%) accurate placements. These findings are not comparable to our study, As this is our first study in our country [23]. Electromagnetic neuronavigation guided ventriculoperitoneal shunt surgery that's Grouped under Group B had 50 % catheter tip placement of Grade I. Wilson et al showed 88% Grade I placement using neuronavigation guided ventriculoperitoneal shunt surgery [20]. 93.33% Grade I placement using neuronavigation guided ventriculoperitoneal shunt surgery was found by Raj et al [24]. Dawood et al reported that 78% patients in Grade 1 placement in neuronavigation study Group [25]. Sampath et al from USA found only 1.4% failure in V-P shunt surgery using electromagnetic neuronavigation [26]. These studies are not comparable to our study because this technique is quite newer in Bangladesh and all equipment's are always not functional and more expertisation is needed for surgery. In our study 18 participants had Grade I catheter tip placement of which 15(83.33%) were from Group B and 3(16.67%) from Group A. Total 28 patients had Grade II catheter tip placement of which 13(46.42%) were from Group B and 15(53.57%) from Group A. 14 patients had Grade III placement, 2(14.28%) from Group B and 12(85.71%) from Group A. So, there is a significant difference in Grade I and Grade III between Group A and Group B. Chi square test and Fisher's exact test was done to measure the *P* value, where significant result was found Grade II placement of both Groups. After surveying of data and comparing the two methods we can declare that rate of hydrocephalus is more among 0-1 years of age with congenital anomaly. Male predominance was noted. About 50% of the patients undergone V-P shunt surgery by neuronavigation system had Grade I placement where only 10% patients with conventional free hand technique had Grade I placement. So, it is clearly evident that electromagnetic neuronavigation guided ventriculoperitoneal shunt surgery had better outcome.

CONCLUSION

Frameless neuronavigation is a valuable tool to optimize the trajectory and final position of shunt catheter in the ventricle. A significant proportion of shunt failure was due to obstruction of the ventricular catheter caused by inaccurate placement of the shunt catheter. This can be reduced significantly by using electromagnetic neuronavigation system. In conclusion, the use of neuronavigation system in routine shunt surgery can eliminate poor shunt placement resulting in a dramatic reduction in shunt failure rates.

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CONFLICT OF INTEREST
None declared

ETHICAL CONSIDERATION
The study was approved by ethical review committee.

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