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Analysis of Variation in Radiological Parameters in Congenital Hydrocephalus After Ventriculoperitoneal Shunt Placement and Its Association with the Functional Outcome

Tehniat Khaliq[1], Shafin Bin Amin[1]*, Ghulam Muhammad Brohi[1], Jahan Jarwar[1], Rabbia Aqeel[2] and Allah Bux[1]

[1]Department of Neurosurgery, Jinnah Postgraduate Medical Center, Karachi, Pakistan

[2]Department of Medicine, Dow Medical College, Karachi, Pakistan

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***Corresponding author:** Amin SB, Department of Neurosurgery, Jinnah Postgraduate Medical Centre, Karachi, Pakistan, E-mail: Shafin10th@gmail.com

ABSTRACT

A disease known as hydrocephalus is defined by an abnormal buildup of Cerebrospinal Fluid (CSF) in the brain's ventricles, which can be caused by either excessive CSF production or poor absorption. It may develop later in life (acquired) or be present from birth (congenital). Congenital hydrocephalus is further divided into two categories: non-communicative hydrocephalus, which happens when CSF drainage channels are blocked and communicating hydrocephalus, in which the ventricular system is unharmed. Congenital hydrocephalus is brought on by several risk factors, such as infections, genetic disorders, preterm birth and structural abnormalities such as Chiari malformations, Dandy-Walker malformations, neural tube defects, cerebral aqueduct stenosis and corpus callosum agenesis.

Keywords: Congenital hydrocephalus, Cerebrospinal fluid, Ventriculoperitoneal

Abbreviations: CMT: Cortical Mantle Thickness; Fd/ihd: Frontal Horn to Interhemispheric Distance; Vp: Ventriculoperitoneal Shunt; Icp: Intracranial Pressure; Csf: Cerebrospinal Fluid

1. Introduction

A disease known as hydrocephalus is defined by an abnormal buildup of Cerebrospinal Fluid (CSF) in the brain's ventricles, which can be caused by either excessive CSF production or poor absorption. It may develop later in life (acquired) or be present from birth (congenital)[1]. Congenital hydrocephalus is further divided into two categories: non-communicative hydrocephalus, which happens when CSF drainage channels are blocked and communicating hydrocephalus, in which the ventricular system is unharmed. Congenital hydrocephalus is brought on by several risk factors, such as infections, genetic disorders, preterm birth and structural abnormalities such as Chiari malformations, Dandy-Walker malformations, neural tube defects, cerebral aqueduct stenosis and corpus callosum agenesis[2,3]. Pharmacological methods such as acetazolamide and surgical procedures like endoscopic third ventriculostomy and Ventriculoperitoneal (VP) shunt implantation are used to treat hydrocephalus. The most popular and successful treatment among these is still VP shunt insertion[4]. To assist CSF drainage, a catheter is inserted into the brain's ventricular system, with its distal end placed in the peritoneal cavity. VP shunting improves neurological function and decreases ventricular size; these improvements are frequently assessed using radiological

markers. These postoperative radiological findings, however, vary widely, which has sparked continuous discussion on their relationship to long-term functional outcomes[5]. Evans' index, the frontal horn to inter caudate distance (FH/IHD) ratio, temporal horn size and Cortical Mantle Thickness (CMT) are some of the important radiological characteristics that are used to evaluate hydrocephalus and forecast prognosis. The degree of parenchymal thinning brought on by prolonged ventricular enlargement is reflected in CMT; higher thinning is linked to worse neurological outcomes[6]. A common indicator of ventricular enlargement is Evans' index, which is determined by dividing the greatest width of the frontal horns by the maximum biparietal diameter. Higher values of this index signify more severe hydrocephalus and a poorer prognosis[7]. Another measure of ventricular volume is the FH/IHD ratio; larger values indicate more ventricular dilatation and the detrimental consequences it has on deep brain structures and neurodevelopment[8]. A common early indicator of hydrocephalus is temporal horn enlargement, which usually occurs before other ventricular areas dilate. After shunt surgery, persistent temporal horn dilatation could indicate poor shunt function or insufficient CSF diversion[9]. Although these radiological markers offer important information on the course of hydrocephalus and the effectiveness of treatment, there is ongoing discussion regarding their prognostic utility. A more thorough approach to patient evaluation is required, as some research indicates that gains in neurological function do not necessarily follow ventricular size reduction following shunting[10,11]. To improve understanding of prognosis in the management of hydrocephalus, this study intends to examine changes in these radiological markers and their relationship to functional results.

2. Methodology

2.1. Study design

The study was conducted in the Neurosurgery Department of Jinnah Post Graduate Medical Centre, a tertiary care hospital in Karachi, using a retrospective cross-sectional research methodology. It comprised 50 congenital hydrocephalus patients who were prospectively recruited and monitored for a year between 02-08-2021 and 02-08-2022. Participants were chosen at random from the Neurosurgery Department of Jinnah Post-Gradual Medical Center in Karachi.

2.1.1. Criteria for inclusion: Patients with congenital hydrocephalus, regardless of gender (male or female), have voluntarily consented after being informed that their personal information will be kept anonymous and that no publications will utilize it.

2.1.2. Exclusion criteria: Patients without consent, adult populations, patients admitted in other facilities apart from Jinnah Postgraduate Medical Center, children with other congenital defects and people who do not meet the requirements for congenital hydrocephalus are among the exclusion criteria.

2.1.3. Methods of data collection: With institutional review board consent, data was gathered at the Neurosurgery Department. Each patient's age, gender and the cause of their hydrocephalus were gathered from their hospital records, along with information about their history and radiological tests, which included measurements of the temporal horn's size, Evan's ratio, FH/ID ratio and cortical mantle thickness.

2.1.4. Data analysis: Using SPSC 23.0, the data was examined after a year of patient follow-up. Descriptive statistics (mean, standard deviation) were employed to compile participant attributes such as cortical mantle thickness, Evan's ratio, FH/ID ratio and temporal horn size.

3. Results

3.1. Study population and demographics

The study included 50 individuals in all, whose mean age was 6.8 months. There was a greater percentage of females in the study population, as evidenced by the fact that 18 (36%) of the participants were male and 32 (64%) were female. Evans ratio, cortical mantle thickness, FH/ID ratio and temporal horn size were the four main radiological characteristics that were the focus of the analysis and changes were evaluated throughout a one-year follow-up period. The overview of observed changes in all outcomes is highlighted in (Table 1).

Table 1: Summary of observed changes in outcomes.

Outcome	Increase (%)	No Change (%)	Decrease (%)
Cortical mantle thickness	28%	58%	14%
Evans ratio	28%	14%	58%
FH/ID ratio	14%	56%	30%
Temporal horn size	34%	Varied	0%

3.2. Changes in Evans ratio

In 29 individuals, the Evans ratio, a crucial measure of ventricular enlargement dropped, indicating a general decrease in ventriculomegaly. Seven patients (14%) had no discernible change, whereas 14 patients (28%) displayed an increase, suggesting possible hydrocephalus development. These changes were confirmed to be non-random by the chi-square test, which revealed a highly significant difference (p=0.00051). Although a small percentage of patients showed worsening ventricular dilatation, the large percentage of patients who experienced a decrease indicates an overall favorable outcome. The variations in the Evans ratio are shown in (Table 2 and Figure 1).

Table 2: Evans ratio.

Change Type	Number of Patients	Percentage (%)
Increase	14	28%
No change	7	14%
Decrease	29	58%
Significance	p=0.00051	Highly Significant

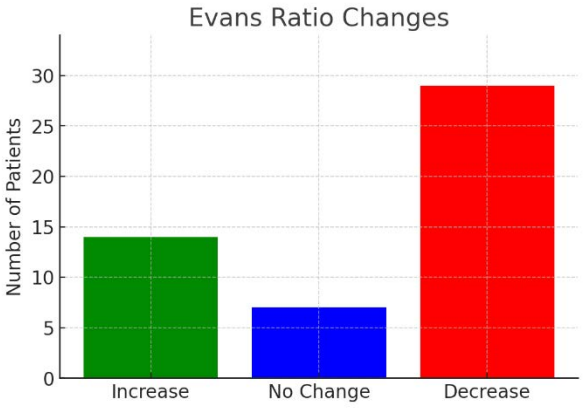

Figure 1: Bar graph of Evans ratio.

3.3. Changes in cortical mantle thickness

In 14 patients (28%), cortical mantle thickness, a measure of brain parenchymal preservation increased, suggesting possible neuroprotection or brain tissue recovery. On the other hand, 7 patients (14%) showed a decline, indicating a development of cortical thinning associated with hydrocephalus. 29 individuals or 58% of the total, did not exhibit any discernible change. The validity of these findings was supported by statistical analysis, which showed a highly significant difference (p=0.00051). Although the decrease in 14% of cases is still concerning, the increase in cortical thickness in 28% of patients is a positive sign. (Figure 2 and Table 3) display the thickness of the cortical mantle.

Table 3: Cortical mantle thickness changes.

Change Type	Number of Patients	Percentage (%)
Increase	14	28%
No change	29	58%
Decrease	7	14%
Significance	p = 0.00051	Highly Significant

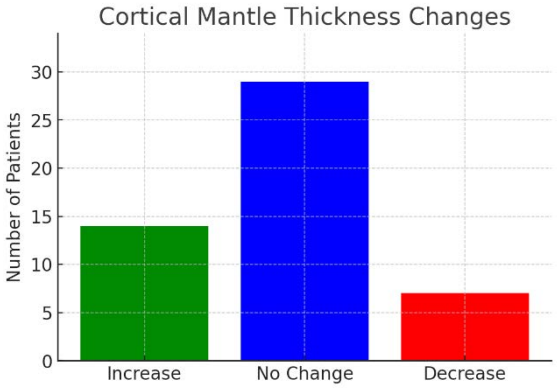

Figure 2: Bar graph of cortical mantle thickness.

3.4. Changes in FH/ID ratio

Fifteen patients (30%) had a decrease in the frontal horn to interhemispheric distance (FH/ID) ratio, indicating improved ventricular dimensions. Throughout the trial, 28 patients (56%) exhibited no discernible change, while 7 individuals (14%) displayed an increase. A significant difference was confirmed by the chi-square test (p= 0.00118), suggesting that variations in the FH/ID ratio followed a significant pattern. Compared to the Evans ratio and cortical thickness, the FH/ID ratio may be less vulnerable to short-term fluctuations, as indicated by the high percentage of patients (56%) who showed no change. (Figure 3 and Table 4) display the fd/ihd ratio.

Table 4: FH/ID ratio changes.

Change Type	Number of Patients	Percentage (%)
Increase	7	14%
No change	28	56%
Decrease	15	30%
Significance	p=0.00118	Significant

3.5. Changes in temporal horn size

17 patients (34%) had a decrease in temporal horn size, indicating an improvement in the distribution of CSF. The outcomes of the remaining patients, however, were inconsistent, making it difficult to distinguish between those who had an increase and those who did not. The absence of a significant chi-square result precludes drawing firm conclusions about the overall effect, even if a size reduction is usually advantageous. To evaluate the clinical importance of temporal horn size changes, more research is required that includes exact categorization. Changes in temporal horn size are displayed in (Table 5 and Figure 4).

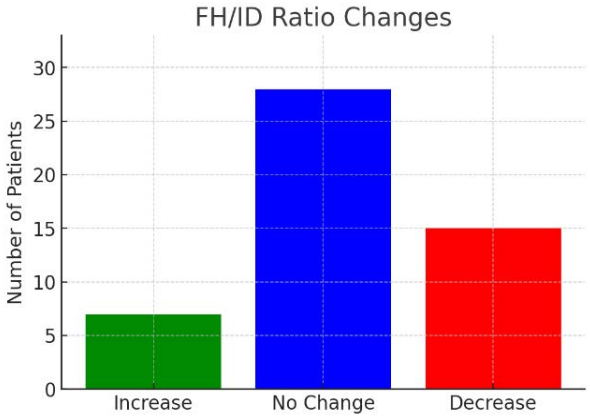

Figure 3: Bar graph of fd/the ratio.

Table 5: Temporal horn size changes.

Change Type	Number of Patients	Percentage (%)
Reduced	17	34%
Other variations	33	Varied
Significance	Not statistically significant	-

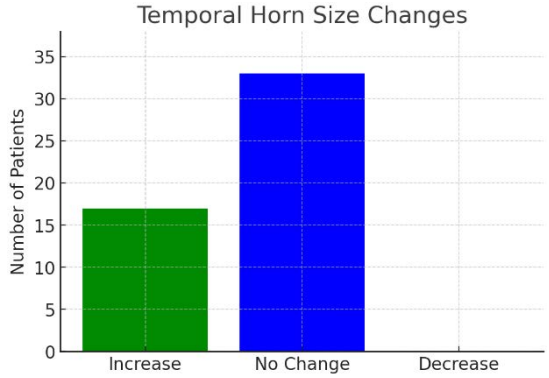

Figure 4: Bar graph of temporal horn changes.

3.6. Interpretation of chi-square test results

To ascertain if the observed changes in the Evans ratio, cortical mantle thickness and FH/ID ratio were statistically significant rather than random fluctuations, the chi-square (χ^2) test was employed. The findings demonstrated that all three measures changed significantly throughout the follow-up period, confirming that there were significant changes in ventricular size, brain tissue thickness and CSF distribution. A robust trend of improvement was confirmed by extremely significant changes ($p<0.00051$) in the Evans ratio and cortical mantle thickness. Although most patients (56%), the FH/ID ratio also showed substantial volatility (p=0.00118), indicating that this parameter may be less sensitive to short-term impacts. Chi-square test results are displayed in (Table 6).

Table 6: Chi-square test results.

Outcome	Chi-Square Value (χ^2)	p-Value
Evans Ratio	15.16	0.00051
Cortical Mantle Thickness	15.16	0.00051
FH/ID Ratio	13.48	0.00118

4. Discussion

To better understand the impact of several radiological measures in post Ventriculoperitoneal shunt (VP) implantation in congenital hydrocephalus and how they relate to functional results, we conducted this study. Evans ratio, Cortical Mantle Thickness (CMT), (fd/ihd) ratio and temporal horn size were the main focus of this investigation, which was carried out in a tertiary care hospital. The findings showed notable variations in these indices over 12 months, with differing degrees of influence on the preservation of brain tissue and the reduction of ventricular size.

An essential indicator for forecasting ventricular hypertrophy is the Evans ratio. The majority of the patients in our study had an overall decrease in ventricular volume in addition to improved functional results. Tisell et al.[7] have reported similar results, demonstrating a decrease in ventricular size but no discernible improvement in cognitive outcomes. Furthermore, Novak et al.[12] demonstrated a comparable improvement in ventricular volume and neurological results, but they also emphasized the importance of other parameters, such as cerebral perfusion and periventricular edema, in enhancing neurological outcomes rather than only the Evans index. Limbrick et al.[11] on the other hand, demonstrated a comparable decrease in ventricular size but no improvement in functional outcomes. This implies that there is no correlation between cognitive reaction and ventricular size alone. The extremely statistically significant difference (p=0.00051), however, indicates that these results were not the result of chance. Another endpoint that was evaluated for our study was Cmt. It is a sign of ventricular enlargement-induced cerebral compression. A third of the population showed a rise in CMT, according to our survey, while the majority showed no change. In a similar vein, Vinchon et al.[10] showed a stronger neurological response and a notable rise in CMT. McGovern, et al.[6] demonstrated a partial manifestation of this impact, demonstrating a decrease in ventricular size without improving neurological state. Given that patients with chronic hydrocephalus did not exhibit any improvement in their neurological state following shunt surgery, this underscored the importance of prompt intervention. As McAlister et al.[13] show, this effect is also important in situations when CMT was not raised after surgery. In a similar vein, Kulkarni et al.[5] reported neurological improvement despite no change in CMT. Chong et al.[14] also observed this effect, showing that although some patients had changes in CMT, others did not, indicating the involvement of other factors like cerebral perfusion and white matter integrity.

Another measure of ventricular capacity was the fh/ihd ratio. The bulk of the patients in our study showed no response, whereas one-third of the population responded favorably. These results are consistent with those of Coenen et al.[15] who found high preoperative FH/ID ratios were associated with neurodevelopmental impairment. However, postoperative alterations did not always indicate functional recovery because deep brain areas may sustain irreparable damage even with CSF diversion. Kim et al.[16] also exhibited similar results, demonstrating that improvement in neurological state is not predicted by the extent of reduction. Furthermore, he emphasizes that the fh/ihd ratio should be assessed in conjunction with periventricular edema and white matter integrity rather than being utilized as a stand-alone metric. Greater percentages of the unchanging ratio, however, imply that this statistic may not be as sensitive as others. A common early sign of hydrocephalus is temporal horn growth. While some patients experienced a decrease in temporal horn size, the majority of our patients experienced a range of outcomes. Kulkarni et al.[5] recently brought attention to these discrepancies by showing that shunt revision rates are increased by prolonged post-operative temporal horn dilatation. Similarly, Novak et al.[12] said that this metric is not a reliable indicator of neurological condition because of the irregularities they found in it. Changes in temporal horn size were not statistically significant, in contrast to Evans' ratio and CMT, indicating that this metric by itself could not be a trustworthy prognostic indicator as proposed by Novak et al.[12]

5. Limitations

It is important to recognize the limitations of our study, even if it offers important insights into the link between radiological measures and functional outcomes after Ventriculoperitoneal (VP) shunt installation in congenital hydrocephalus. First off, we only used a small sample size and only one tertiary care hospital for our study. This could restrict our findings' applicability to broader, more varied groups. Our findings need to be confirmed by bigger cohorts in future multicentre research. Second, our study only tracked patients for a year after surgery, which might not be enough time to record long-term neurological effects and problems from the shunt. Over time, some functional gains or deteriorations might become apparent. Thirdly, we mostly used standard MRI and CT data, which might not adequately represent changes in the microstructure of the brain, cerebral perfusion or white matter integrity. More sophisticated methods like phase-contrast MRI, functional MRI or Diffusion Tensor Imaging (DTI) may offer a more thorough picture of brain recovery following a shunt. Last but not least, we did not fully analyze confounding clinical variables, such as patient comorbidities, shunt revisions, Intracranial Pressure (ICP) monitoring and genetic impacts. Future research must include a more thorough clinical evaluation because these factors may have a substantial impact on both radiological alterations and functional recovery.

6. Conclusion

The limits of utilizing ventricular size alone to predict functional recovery are highlighted by this study, which also emphasizes the heterogeneity in radiological responses after VP shunt insertion. Although metrics like Evans' ratio, CMT, FH/ID ratio and temporal horn size offer insightful information, there is still inconclusive evidence linking them to therapeutic improvement. To improve prognosis and customize hydrocephalus treatment to meet the needs of each patient, multimodal assessment techniques that integrate radiographic, clinical and biomarker-based evaluations are crucial.

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