Pediatric Hydrocephalus in Brazil Public Health System: the Reality of a Developing Country in the Past 13 Years

Leonardo de Macedo Filho (ldemacedofilho@pennstatehealth.psu.edu)
Penn State Health Milton S. Hershey Medical Center

Alireza Mansouri
Penn State Health Milton S. Hershey Medical Center

Buse Sarigul
Tuzla Public Hospital

Ana Vitoria Diogenes
University of Fortaleza

Caio Kacem
University of Fortaleza

Gustavo Torquato
University of Fortaleza

Patricia Andrade
University of Fortaleza

Elias Rizk
Penn State Health Milton S. Hershey Medical Center

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Abstract

PURPOSE

Pediatric hydrocephalus is a significant challenge in neurosurgery, particularly in resource-limited settings. This study focuses on the landscape of pediatric hydrocephalus neurosurgery in Brazil, a developing country, over the past 13 years.

METHODS

Data were collected from the Brazilian Hospital Information System, Live Birth Information System, and Mortality Information System records in the DATASUS (Departamento de Informática do SUS) database among January 2008 and the July 2021. Various health indicators were analyzed, including hospitalizations, treatment options, costs, and mortality rates.

RESULTS

During the period of study, Brazil recorded 8,493 new diagnoses of congenital hydrocephalus in live births, with 1,123 cases associated with spina bifida. The prevalence of congenital hydrocephalus was 241 cases per 100,000 live births, and 210 cases per 100,000 live births were attributed to congenital hydrocephalus not related to spina bifida. A total of 730 perinatal mortality cases related to congenital hydrocephalus were reported, with no clear trend over the 12-year period. The average number of perinatal mortality cases was 60.83 ± 13.98 per year. There were 1,063 infant mortality cases associated with hydrocephalus and 3,122 cases associated with congenital hydrocephalus, with no clear trend observed. The highest mortality rates for both diagnoses occurred between 3 to 5 months of age. Ethnicity and age were found to have significant relationships with mortality rates. A total of 217,900 hydrocephalus-related procedures were performed, with an increase in mean hospitalization cost and procedure numbers over the 13-year period. Mean cost per procedure had a significant negative effect on mean length of stay, while average professionals' salary did not have a significant effect.

CONCLUSION

Pediatric hydrocephalus in Brazil's public health system is a significant burden. Congenital hydrocephalus prevalence and mortality rates emphasize the need for better diagnosis and treatment. Early diagnosis, prenatal care, and adequate resources are crucial. This study offers insights into pediatric hydrocephalus in a developing country, highlighting challenges and future directions for improved care.

INTRODUCTION

Pediatric hydrocephalus remains a significant challenge in neurosurgery, with a high burden of morbidity and mortality in affected children[1]. The condition arises from the abnormal accumulation of cerebrospinal fluid, causing ventricular dilation and compression of brain structures[1]. Several risk factors, such as low
socioeconomic status, maternal diabetes, prematurity, birth weight less than 1500 grams, and male sex, have been identified for hydrocephalus in this population [2]. Despite progress in diagnosis and treatment, challenges remain, particularly in resource-limited settings[1, 2].

In pediatric cases, congenital hydrocephalus is most frequently associated with Chiari malformations, intraventricular masses, X-linked hydrocephalus, primary aqueductal stenosis, Dandy-Walker cysts, and gliosis due to intrauterine infection[1]. Other etiologies contributing to hydrocephalus include genetic defects, trauma, infection, intracerebral hemorrhage, and teratogens[2].

Pediatric hydrocephalus is more prevalent in developing countries and presents a significant care burden compared to developed countries[1–10]. Several factors contribute to the higher incidence, including cultural beliefs, nutritional deficiencies, low infant birth weight, a higher incidence of perinatal and neonatal infections, delayed antenatal diagnosis, political instability, poverty, limited access to neurosurgical treatment, insufficient resources, low infrastructure capacity of tertiary health centers, great distances to these centers, and low family income[1, 4–6]. Additionally, the scarcity of available and trained neurosurgeons results in delayed presentation to medical care and higher morbidity and mortality rates[1, 7].

Hydrocephalus is a condition that requires early diagnosis and management to reduce morbidity and mortality. Prenatal diagnosis is an essential component of the management of this condition. However, in developing countries, where the incidence of congenital hydrocephalus is higher, and resources for prenatal diagnosis are limited, there is a major challenge in providing adequate prenatal diagnosis. This can lead to delays in diagnosis and treatment, resulting in increased morbidity and mortality rates[8, 9].

Ventricular shunt implantation is the primary treatment modality for pediatric hydrocephalus. However, this procedure is not without risks, including subdural hematoma, strokes, catheter misplacement, mechanical obstruction, infection, and death[3, 7, 10]. The rate of shunt revision or replacement is high, with up to 85% requiring revision within 10 years of insertion, contributing to over half of the overall hydrocephalus cost to the healthcare system in the USA[2]. This underscores the urgent need for improved diagnostic and treatment strategies for hydrocephalus, particularly in developing countries where access to appropriate care is limited[8–10]. In Brazil, hydrocephalus affects one to three children per 1000 births. This highlights the importance of addressing the challenges and future directions in the management of pediatric hydrocephalus in developing countries[11].

The objective of this study is to provide a comprehensive characterization of the current landscape of pediatric hydrocephalus neurosurgery in Brazil, with a specific focus on congenital cases. Our analysis includes an assessment of the prevalence of hydrocephalus, available treatment options, hospitalization costs associated with shunt procedures, and mortality rates of pediatric hydrocephalus. To accomplish this, we utilized a reliable database of Brazilian health information, including sources such as the Ministry of Health's DATASUS website, as well as relevant publications on hospital information systems and health information experiences in Brazil [12–14].

METHODS
The hydrocephalus cohort for this study was identified through the Brazilian Hospital Information System (Sistema de Informações Hospitalares do Sistema Único de Saúde [SIHSUS]), Live Birth Information System (Sistema de Informação de Nascidos Vivos [SINASC]), and Mortality Information System (Sistema de Informações sobre Mortalidade [SIM]) records in the DATASUS (Departamento de Informática do SUS) database from January 2008 to July 2021. The DATASUS database is developed and maintained by the Brazilian federal government’s information technology department for the Brazilian Unified Health System (Sistema Único de Saúde; SUS), and is responsible for collecting, processing, disseminating, and managing health information from both public and private sectors in Brazil. This study relied on DATASUS as a reliable source of health information for the characterization of pediatric neurosurgery in Brazil, specifically hydrocephalus cases, including current burden, types of treatment available, hospitalization cost for shunt procedures, and mortality of congenital hydrocephalus.

The present study collected and categorized data into three groups: neurosurgical procedures (hospital information); congenital hydrocephalus in perinatal period; fetal, infant and general pediatric mortality in Brazil. Various health indicators were analyzed for each group from the DATASUS database. The hospital information group included indicators such as the number of hospitalizations, mean cost of hospitalization, the average amount paid to professionals, the mortality rate per procedure, and mean length of stay (days) for each neurosurgical shunt procedure. The congenital anomalies or defects in live births group examined the prevalence of hydrocephalus anomalies per live birth declaration. In addition, substantial analysis of mortality rate in infants, fetal, and the general population was conducted, considering age, gender, and race/ethnicity.

To facilitate international comparison, we used the exchange rate of the Brazilian real (R$) to the United States dollar (US$) on the day of data collection (March 03, 2023), where R$1 was equivalent to US$0.19. While the total cost of a procedure remains fixed, hospitalization cost can vary depending on factors such as length of stay, complexity, and patient outcomes and complications. The mortality rate is defined as the hospital mortality rate per 100 people hospitalized, and the mean length of stay is calculated by dividing the sum of days from admission to discharge by the number of patients hospitalized.

**Statistical Analysis**

We conducted the statistical analysis using R software version 4.0.3. The chi-squared test was utilized to determine any significant associations between gestational age, delivery time, gender, ethnicity, and age with perinatal and pediatric mortality in cases of congenital hydrocephalus and hydrocephalus. Additionally, we performed multiple linear regression analysis to examine the relationship between shunt procedure costs and salaries paid to the healthcare professionals with outcomes such as length of stay and mortality. In this study, we set the significance level at 0.05. If the p-value was below 0.05, we rejected the null hypothesis, indicating a significant association between the studied factors.

**RESULTS**

**Congenital Hydrocephalus in Perinatal Period**
During the studied period, we recorded a total of 8493 new diagnoses of Congenital Hydrocephalus in live births. Of these, 1123 cases were associated with spina bifida, while 713 cases presented with spina bifida without hydrocephalus (Table 1). Given that Brazil had 34,973,593 births between 2008 and 2019, the prevalence of congenital hydrocephalus was 241 cases per 100,000 live births and 210 cases per 100,000 live births were attributed to congenital hydrocephalus not related to spina bifida.

Table 1

<table>
<thead>
<tr>
<th>Category ICD-10</th>
<th>Number of Cases</th>
<th>Prevalence rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Other congenital hydrocephalus</td>
<td>843</td>
<td>0.0024%</td>
</tr>
<tr>
<td>Unspecified congenital hydrocephalus</td>
<td>6527</td>
<td>0.0186%</td>
</tr>
<tr>
<td>Cervical myelomeningocele with hydrocephalus</td>
<td>249</td>
<td>0.0007%</td>
</tr>
<tr>
<td>Thoracic myelomeningocele with hydrocephalus</td>
<td>49</td>
<td>0.0001%</td>
</tr>
<tr>
<td>Lumbar myelomeningocele with hydrocephalus</td>
<td>179</td>
<td>0.0005%</td>
</tr>
<tr>
<td>Sacral myelomeningocele with hydrocephalus</td>
<td>107</td>
<td>0.0003%</td>
</tr>
<tr>
<td>Unspecified myelomeningocele with hydrocephalus</td>
<td>539</td>
<td>0.0015%</td>
</tr>
<tr>
<td>Cervical myelomeningocele without hydrocephalus</td>
<td>97</td>
<td>0.0003%</td>
</tr>
<tr>
<td>Thoracic myelomeningocele without hydrocephalus</td>
<td>50</td>
<td>0.0001%</td>
</tr>
<tr>
<td>Lumbar myelomeningocele without hydrocephalus</td>
<td>329</td>
<td>0.0009%</td>
</tr>
<tr>
<td>Sacral myelomeningocele without hydrocephalus</td>
<td>237</td>
<td>0.0007%</td>
</tr>
</tbody>
</table>

A total of 730 perinatal mortality cases related to congenital hydrocephalus were recorded in Brazil from 2008 to 2019. The number of cases varied from year to year, with the highest number of cases reported in 2012 (n = 84) and the lowest in 2019 (n = 37). No clear trend in the number of cases over the 12-year period was observed. The average number of perinatal mortality cases due to congenital hydrocephalus in Brazil from 2008 to 2019 was 60.83 ± 13.98 cases by year. Of these, 424 (58%) cases were male, 280 (38%) were female, and 26 (4%) were of unknown gender.

The highest mortality rate was observed in the 32 to 36 weeks of gestational age, with 204 deaths, followed by the 37 to 41 weeks, with 151 deaths. In contrast, the lowest perinatal mortality rate was observed in the 42 weeks and more, with only 6 deaths (Table 2). The chi-squared test indicated a significant association between gestational age and perinatal mortality of congenital hydrocephalus (p < 0.001). Most cases (89.86%) occurred before delivery, followed by during delivery (3.42%) and after delivery (0.14%), while a significant proportion of cases (6.3%) had an unknown time of delivery. The chi-squared test showed a statistically significant association between the time of delivery and perinatal mortality of congenital hydrocephalus in Brazil (p = 0.01462).
Table 2
Perinatal Mortality of Congenital Hydrocephalus in Brazil from 2008 to 2019 by Gestational Age.

<table>
<thead>
<tr>
<th>Category</th>
<th>ICD-10</th>
<th>Less than 22 weeks</th>
<th>22 to 27 weeks</th>
<th>28 to 31 weeks</th>
<th>32 to 36 weeks</th>
<th>37 to 41 weeks</th>
<th>42 weeks and more</th>
<th>Unknown</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Congenital</td>
<td>Hydrocephalus</td>
<td>28</td>
<td>146</td>
<td>142</td>
<td>204</td>
<td>151</td>
<td>6</td>
<td>53</td>
<td>730</td>
</tr>
</tbody>
</table>

Hydrocephalus and Congenital Hydrocephalus in Infants and Pediatric Population

The analysis revealed that there were a total of 1063 infant mortality cases associated with hydrocephalus, with an average of 88.58 ± 20.11 cases per year. In contrast, congenital hydrocephalus had a higher number of infant mortality cases, with a total of 3122 cases and an average of 260.17 ± 41.35 cases per year. However, there was no clear trend observed in the number of mortality cases over the 12-year period for both diagnoses (Fig. 1). Regarding the gender distribution, 575 (54.09%) of the hydrocephalus mortality cases were male, and 488 (45.91%) were female. Similarly, 1670 (53.49%) of the congenital hydrocephalus mortality cases were male, and 1434 (45.93%) were female, while 18 (0.58%) were unknown. The chi-square test indicated that there was a statistically significant relationship between gender and infant mortality for both hydrocephalus and congenital hydrocephalus (p < 0.001).

The highest mortality rate in infants occurred between the ages of 3 to 5 months, with 514 deaths, followed by the age group of 6 to 11 months, with 398 deaths. The lowest infant mortality rate was found in those between 1 to 6 days old, with only 6 deaths. Similarly, for infants with congenital hydrocephalus, the highest mortality rate occurred between the ages of 3 to 5 months with 808 deaths, followed by the age group of 6 to 11 months with 565 deaths, and the lowest mortality rate was observed in those between 1 to 6 days old (Table 3). The chi-square test indicated that there is strong evidence of a significant relationship (p < 0.001) between age and mortality for both diagnoses.

Table 3
Infant Mortality of Hydrocephalus and Congenital Hydrocephalus in Brazil from 2008 to 2019 by Age.

<table>
<thead>
<tr>
<th>ICD-10 Category</th>
<th>Less than 24 hours</th>
<th>1 to 6 days</th>
<th>7 to 27 days</th>
<th>28 days to 2 months</th>
<th>3 to 5 months</th>
<th>6 to 11 months</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrocephalus</td>
<td>7</td>
<td>4</td>
<td>6</td>
<td>134</td>
<td>514</td>
<td>398</td>
<td>1063</td>
</tr>
<tr>
<td>Congenital hydrocephalus</td>
<td>477</td>
<td>404</td>
<td>459</td>
<td>409</td>
<td>808</td>
<td>565</td>
<td>3122</td>
</tr>
</tbody>
</table>

The distribution of ethnicity among hydrocephalus and congenital hydrocephalus mortality cases was analyzed in infants. For hydrocephalus mortality cases, the highest percentage of cases was recorded among pardos (38.01%), followed by white (44.87%). Black infants had the lowest percentage of cases (2.92%), the ethnicity of 12.23% of the cases was unknown. In contrast, for congenital hydrocephalus mortality cases, the highest percentage of cases was among pardos infants (42.09%), followed by white (43.43%). Black infants had the lowest percentage of cases (1.76%), and 10.25% of cases had an unknown ethnicity. The chi-square
test result shows that there is a statistically significant relationship between ethnicity and the occurrence of both hydrocephalus and congenital hydrocephalus \( (p < 0.001) \) mortality.

We retrieved mortality data for pediatric hydrocephalus and congenital hydrocephalus from DATASUS, which were classified into five categories of pediatric ages: less than 1 year, 1 to 4 years, 5 to 9 years, 10 to 14 years, and 15 to 19 years (Fig. 2). The chi-square test revealed a statistically significant relationship between age and the occurrence of hydrocephalus and congenital hydrocephalus mortality \( (p < 0.001) \).

Overall Shunt Procedures in a Developing Country

A total of 217,900 procedures related to hydrocephalus were performed during this period, with 1,400 being lumboperitoneal (LP) shunts, 94,431 ventriculosubgaleal (VSG) shunts, and 104,115 ventriculoperitoneal (VP)/ventriculoatrial (VA)/ventriculopleural (VLP) shunts, along with 14,361 shunt revisions and 3,593 shunt removals (Table 4).

<table>
<thead>
<tr>
<th>Shunt Procedure</th>
<th>Performed procedures</th>
<th>Total Cost for Hospitalization (USD)</th>
<th>Average professionals’ salary (USD)</th>
<th>Mean Cost per Procedure (USD)</th>
<th>Mean Length of Stay (days)</th>
<th>Mortality Rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lumboperitoneal (LP) Shunt</td>
<td>1,400</td>
<td>769,174.91</td>
<td>130.25</td>
<td>549.41 ± 15.28</td>
<td>12.3</td>
<td>4.86</td>
</tr>
<tr>
<td>Ventriculosubgaleal (VSG) Shunt</td>
<td>94,431</td>
<td>87,167,841.94</td>
<td>130.96</td>
<td>923.08 ± 24.56</td>
<td>12.7</td>
<td>28.96</td>
</tr>
<tr>
<td>Ventriculoperitoneal (VP) / Ventriculoatrial (VA) / Ventriculopleural (VLP) Shunt</td>
<td>104,115</td>
<td>73,097,929.49</td>
<td>159.11</td>
<td>702.09 ± 16.29</td>
<td>10.6</td>
<td>5.18</td>
</tr>
<tr>
<td>Shunt Removal</td>
<td>3,593</td>
<td>1,488,064.99</td>
<td>104.24</td>
<td>414.16 ± 14.49</td>
<td>12.4</td>
<td>6.01</td>
</tr>
<tr>
<td>Shunt Revision</td>
<td>14,361</td>
<td>6,652,546.38</td>
<td>127.18</td>
<td>463.24 ± 11.47</td>
<td>8.9</td>
<td>3.97</td>
</tr>
</tbody>
</table>

The mean hospitalization cost for each shunt procedure was $772.57, and the average amount paid to professionals per procedure was $143.00. The mortality rate and mean length of stay for these procedures were 15.42% and 11.4 days, respectively (Table 4).

After 13 years, the mean cost of hospitalization, in comparison to 2008, has increased by 42.58% (Fig. 3). The number of procedures increased by 19.78% in the 2008 to 2019 period, a mean raises of 1.73% per year (Fig. 4).
For the mortality rate model, the multiple linear regression analysis shows that neither mean cost per procedure nor average professionals' salary have a statistically significant effect on the mortality rate. This is based on the p-values, which are 0.539 and 0.082 for mean cost per procedure and average professionals' salary, respectively. The adjusted R-squared value of -0.4415 suggests that the model does not fit the data well.

For the mean length of stay model, the multiple linear regression analysis shows that mean cost per procedure has a statistically significant negative effect on mean length of stay (p-value < 0.001), meaning that higher mean cost per procedure is associated with shorter mean length of stay. However, average professionals' salary is not statistically significant (p-value = 0.272), suggesting that it does not have a significant effect on mean length of stay. The adjusted R-squared value of 0.9544 suggests that the model fits the data well.

**DISCUSSION**

Hydrocephalus is a significant health concern affecting children worldwide, with an estimated annual incidence of 50 cases per 100,000 births[1]. While developed countries have an incidence of 0.5-1/1000 live births, 75% of the cases occur in low- and middle-income countries in Latin America, African, and Southeast Asian regions[1, 15–17]. Our study investigated the incidence of congenital hydrocephalus in Brazil, and we found a prevalence of 3.16:1,000 newborns, which is consistent with the incidence reported in other Latin American countries [7, 9, 18].

Our results also revealed a gender and racial disparity in the incidence of hydrocephalus. Male infants were more likely to develop hydrocephalus than female infants. Similarly, the incidence of hydrocephalus was higher among infants of white race and ethnicity, followed by pardo and black. This finding is in line with the demographics of the Brazilian population, which is characterized by significant racial miscegenation[19].

In developed countries, the most common etiologies of hydrocephalus are congenital central nervous system (CNS) malformations and intraventricular hemorrhage (IVH), while infections are the leading cause of hydrocephalus in developing countries[2, 20]. In South Africa, post-infectious hydrocephalus accounts for 40% of cases, and in Uganda, it accounts for 60% of cases[2].

Hydrocephalus burden in low- and middle-income countries is substantial due to limited healthcare access and inadequate prenatal care. In Brazil, challenges in providing adequate care to affected children arise from a shortage of professionals, inadequate infrastructure, and limited access to specialized care in remote regions. To address these issues, efforts include raising awareness, improving prenatal care, enhancing healthcare infrastructure and access, and training professionals to manage hydrocephalus[1, 8].

**Treatment**

Hydrocephalus can be treated through invasive and non-invasive methods depending on the type of neurological dysfunction, the degree of ventricular dilatation, the presence of hypertension, and the location of the expansion process[18, 20]. Non-invasive treatments include the use of drugs such as acetazolamide to stimulate the absorption of cerebrospinal fluid (CSF), inhibit its production, or decrease the brain's water
Lumbar punctures can also be used in cases of intraventricular hemorrhage and normal pressure hydrocephalus[18]. Surgical treatments include resection of obstructive structures such as tumors and implantation of LP, VSG, or VP/VA/VLP shunts[20].

VP shunt is the most common type of shunt performed and was the main surgical treatment in Brazil between 2008 and 2021, followed by VSG shunts[7, 15, 19, 21]. The VSG shunt procedure showed a significant increase in the studied period, as a strategy to reduce the incidence of shunt revisions, and the incidence of slit ventricles is significantly less in this procedure[22]. Although the VSG shunt is not a definitive treatment for hydrocephalus, it serves as an effective mechanism for temporarily reducing the increased intracranial pressure until a permanent treatment is available[23].

The number of procedures related to hydrocephalus increased between 2008–2019 in Brazil, contrasting with a decrease of 6.35% in 2020. This process may be a result of the COVID-19 pandemic since the neurosurgery centers decreased the overall number of procedures[4] according to the recommendations of the Brazilian Society of Pediatric Neurosurgery (Sociedade Brasileira de Neurocirurgia Pediátrica, SBNPed)[24]. These recommendations aim to minimize potential exposure of the patients and health professionals and prevent new cases since children need continuous parental assistance and greater medical support[4, 24].

Complications

Although shunt implantation is a common and effective treatment for hydrocephalus, it is often associated with complications throughout its lifetime[7, 23]. A recent study by Donoho et al. (2021) found that 20% of 3520 pediatric patients required shunt revision within 6 months of surgery[25]. In Brazil, shunt revisions were required for 5.28% of 217,900 procedures, with 1.3% of procedures resulting in shunt removal; however, it is unclear whether these removals were due to shunt failure or hydrocephalus resolution, and the data includes adults[12]. Valve dysfunction and infection were found to be the main complications leading to shunt replacement in a sample of 102 pediatric patients undergoing VP shunt surgery in a tertiary pediatric hospital in Curitiba-PR, Brazil, as well as in a study of 150 consecutive cases at Hospital das Clínicas de Ribeirão Preto-SP, Brazil[19, 20]. Gluski et al. (2020) reported that obstruction of the proximal catheter was the most commonly suspected cause for hardware removal among 228 pediatric patients across four centers in the USA[2].

Mortality

Mortality rates remained stable over the studied period; however, there was a decrease in congenital hydrocephalus mortality, which suggests improvements in infection control and shunt surgery quality, leading to better long-term survival for patients. Limited access to necessary resources, geographical barriers to specialized centers, and a shortage of professionals in poorer regions remain major challenges[5, 26].

Pediatric hydrocephalus is historically associated with high morbidity and mortality rates due to the presence of associated medical conditions. Nevertheless, studies demonstrate that other comorbidities may be the main cause of death rather than hydrocephalus itself[27, 28, 29]. The mortality rate is higher in pediatric patients with untreated hydrocephalus since the cerebral cortex is not yet fully developed. Moreover, severe hydrocephalus that compresses the cortex may reduce overall brain mass and thickness[28, 29]. Patients with
longer follow-up periods demonstrated a higher proportion of mortality, indicating that the time at risk raises mortality rates. However, this also suggests that the management of these patients has improved, including surgical techniques[27]. Ethnicity is a risk factor for mortality, as Hispanic and non-white ethnicities are associated with a higher rate. This finding may reflect cultural variations in the approach to this pathology[27, 28].

**Challenges for Developing Countries**

Developing countries face numerous challenges in improving access to surgeries for pediatric hydrocephalus. These challenges include a lack of information about treatment and social factors such as illiteracy and low levels of education[1, 6]. For example, Melo et al. (2013) found that 46% of caregivers had low levels of education, which was associated with irregular prenatal care[7]. Infrastructure limitations also pose challenges in providing support for patients with hydrocephalus during the perioperative and postoperative periods. This includes the need for periodic imaging, ICU resources, follow-up visits, medications, and surgical equipment[1].

The availability of trained professionals is another challenge. This can be attributed to poor governmental management in some countries and a lack of residency training programs in neurosurgery[1]. These limitations can impact the success of neurosurgeries and contribute to low lifetime mortality rates[4, 5, 6]. Our study found that cost limitations in professionals’ salaries and shunt procedures were significant challenges. Additionally, there is an unequal distribution of neurosurgeons across the continent. For example, in East Africa there is approximately 1 neurosurgeon for every 10 million people and in Sub-Saharan Africa there is 1 for every 5 million people. This is in stark contrast to Europe where there is 1 neurosurgeon for every 100,000 inhabitants[1, 6].

There is also a need for more national studies on hydrocephalus in Brazil as the available research is limited. This includes studies on the impact of hydrocephalus on local and global neurosurgery. Treatment must be based on strong local scientific evidence that can guide families and patients about this condition[15, 26].

Prenatal diagnosis of hydrocephalus is also a major concern in developing countries. A study conducted in Cameroon[8] found that less than half of neural tube defects (NTDs), including hydrocephalus, were detected prenatally due to inadequate prenatal screening programs and awareness among healthcare providers and patients. Another study from northeastern Brazil reported that only a third of cases were diagnosed prenatally due to inadequate prenatal care and ultrasound screening[21]. A descriptive study in Rabat, Morocco also reported that congenital malformations were often diagnosed after birth or at a later stage of pregnancy due to limited access to prenatal screening and diagnosis[10]. These challenges highlight the need for international efforts in public health to improve understanding and access to treatment for pediatric hydrocephalus in developing countries.

**Limitations**

DATASUS is an important database that compiles and unifies Brazilian health information, however, it has limitations. The decentralization of SUS in counties and states may lead to failures in data collection on certain subjects as well as failures in standardization and integration of health data, also, the management of the data collection process is not limited to the DATASUS department, although it is the main core, numerous autonomous centers sometimes do not work in an integrated environment with the DATASUS technological
and regulatory methodologies[13–15, 30]. In an attempt to overcome these limitations and promote better use of the platform, DATASUS has developed some tools, such as TabWin, TabNet, and Health Information Notes[13–15, 30]. This database lacks clinical and qualitative details and does not distinguish some relevant data, such as the shunt procedures for pediatric and adult patients, the causes of pediatric hydrocephalus, and the reasons for shunt revisions or replacements.

CONCLUSION

Our study highlights the challenges and realities of managing pediatric hydrocephalus in the Brazilian public health system. It emphasizes the need for improved prenatal diagnosis, increased access to neurosurgical care, and enhanced strategies for shunt management. Addressing these challenges will require collaborative efforts between healthcare providers, policymakers, and the society to improve the outcomes and quality of life for children with hydrocephalus in Brazil.

Declarations

Author Disclosures: The authors of the article “PEDIATRIC HYDROCEPHALUS IN BRAZIL PUBLIC HEALTH SYSTEM: THE REALITY OF A DEVELOPING COUNTRY IN THE PAST 13 YEARS” declare that this is an original unpublished article that does not transgress any copyright or intellectual property rights of other people and it is not being evaluated for publication in other journals. Every author has contributed substantially to accomplish this work. This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors. All authors have no conflict of interest to report.

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Conflicts of interest/Competing interests

The authors declare that there are no conflicts of interest or competing interests in the research presented in this manuscript.

Availability of data and material

The data and materials used in this study are available upon reasonable request from the corresponding author.

Code availability

The code used in this study is available upon reasonable request from the corresponding author.

Authors’ contributions

LJMMF contributed to the conception, design, data collection, analysis, interpretation, and writing of
the manuscript. BS and AM contributed to the conception, design, interpretation and writing of the manuscript. AVGD, CK, GCPT and PPA contributed to writing of the manuscript. ER contributed to the conception, design, interpretation, and writing of the manuscript. All authors contribute to the revision of the manuscript.

**Ethics approval**

This study was conducted using data from DATASUS, the Brazilian public health system’s database. As such, individual patient consent was waived. Research involving only public domain data that does not identify research participants, or only literature review, without human involvement, does not require approval by the Comite de Etica em Pesquisa – Comissão Nacional de Ética em Pesquisa (CEP – CONEP; Brazilian Research Ethics Committee – Brazilian National Commission for Research Ethics). The use of this data for research purposes is in compliance with national regulations and ethical guidelines.

**Consent to participate**

Not applicable as this study was conducted using data from DATASUS, the Brazilian public health system’s database. As such, individual patient consent was waived. The use of this data for research purposes is in compliance with national regulations and ethical guidelines.

**Consent for publication**

Not applicable as this study was conducted using data from DATASUS, the Brazilian public health system’s database. As such, individual patient consent for publication was waived. The use of this data for research purposes is in compliance with national regulations and ethical guidelines.

**References**


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**Figures**
Figure 1

Infant Mortality of Hydrocephalus and Congenital Hydrocephalus in Brazil from 2008 to 2019 by Year.

Figure 2

Pediatric Mortality

- 15-19 years
- 10-14 years
- 5-9 years
- 1-4 years
- <1 year

Legend:
- Congenital hydrocephalus
- Hydrocephalus
Mortality of Pediatric Hydrocephalus and Congenital Hydrocephalus in Brazil from 2008 to 2019 by Age.

Figure 3

Mean Hospitalization Costs (USD) in Brazil per Year.
Figure 4

Total of Shunt Procedures Hospitalizations in Brazil per Year.