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ORIGINAL RESEARCH

The Hydrocephalus Association Patient-Powered Interactive Engagement Registry (HAPPIER): Design and Initial Baseline Report

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Video abstract

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Purpose: Hydrocephalus is a neurological condition characterized by an accumulation of cerebrospinal fluid (CSF) with no cure and limited treatments. There is a significant gap in hydrocephalus research where patients lack opportunities to voice their perspectives on their condition. The Hydrocephalus Association Patient-Powered Interactive Engagement Registry (HAPPIER) database captures the lived experiences of those affected by hydrocephalus and provides a platform for researchers to access these data or distribute their own surveys, ultimately aiming to improve patient-centered care and outcomes. This publication introduces the registry by highlighting the demographics, etiology, treatments, symptom profiles, and diagnosed comorbidities of the participants.

Methods: The Hydrocephalus Association and a 10-member steering committee developed HAPPIER. Other patient registries, existing surveys and assessments, and University of Utah Data Center faculty guided survey development. The Hydrocephalus Association recruited participants using social and traditional media, medical referrals, and advertisements at events.

Results: Of the 691 survey participants with hydrocephalus, 451 (65.3%) responded for themselves. The majority of the registry was female (55.0%), white (86.0%), and from the United States and territories (87.7%). Most were diagnosed between 0–11 months (46.2%), with congenital hydrocephalus as the most reported etiology (43.8%). Participants reported a shunt(s) as the most prevalent treatment (71.2%) and headaches as the most frequent symptom (60.3%), while 69.9% of participants reported being diagnosed with movement impairments and 70.8% with other health conditions.

Conclusion: HAPPIER is a novel database that addresses gaps in data on non-clinical outcomes of hydrocephalus, which are critical to clinical care and understanding hydrocephalus. Patient perspectives and outcomes remain historically underrepresented. By directly engaging individuals living with hydrocephalus and their caregivers, HAPPIER incorporates essential patient perspectives through planned longitudinal data collection and patient surveys. These data are open to investigators interested in analyzing the collected data.

Plain Language Summary: Hydrocephalus is a lifelong condition where excess fluid builds up in the brain. A significant gap in research is the lack of information on how hydrocephalus affects the daily lives of those with the condition. To bridge this gap, the Hydrocephalus Association created the Hydrocephalus Association Patient-Powered Interactive Engagement Registry (HAPPIER), a patient registry that gathers the real-world experiences from people living with hydrocephalus. This database helps researchers better understand symptoms, treatments, and challenges, ultimately working toward better patient care.

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Experts contributed to the development of HAPPIER, using guidance from existing patient registries and surveys. Participants joined through media recruitment, medical referrals, and outreach events. The registry includes 691 people with hydrocephalus, most of whom answered the survey themselves. More than half are female, and the majority are from the United States. Many were diagnosed as infants (between 0-11 months), with congenital hydrocephalus being the most common etiology. Participants most frequently reported receiving a shunt(s) as treatment and experiencing headaches as the most common symptom. Many participants also experienced movement difficulties and other health conditions.

The HAPPIER registry gathers data on people with hydrocephalus, including their backgrounds, treatments, symptoms, and other health conditions. The goal is to use ongoing surveys to better understand their experiences and find ways to improve quality of life. Researchers can access these data or conduct their own surveys through HAPPIER, giving patients and caregivers a voice in research and ensuring the patient perspective guides advancements in future studies, treatment, support, and clinical care.

Keywords: hydrocephalus, database, patient registry

Introduction

Hydrocephalus is a chronic, multifaceted condition with no cure. It is characterized by an abnormal accumulation of cerebrospinal fluid (CSF) in the ventricles of the brain. Many individuals with hydrocephalus experience a variety of motor, cognitive, neuropsychiatric, quality of life, and developmental impairments.[1–8] Hydrocephalus treatments are limited to a surgically inserted ventricular or lumbar shunt, or an endoscopic third ventriculostomy (ETV) with or without choroid plexus cauterization (CPC), all of which have high rates of failure.[9] Major gaps exist in hydrocephalus research when it comes to tracking, understanding, diagnosing, and ameliorating these outcomes. Much of the existing data comes from clinical research networks, notably the Hydrocephalus Clinical Research Network (HCRN)[10,11] and the Adult Hydrocephalus Research Network (AHCRN).[12] Surgical and clinical data are available, but with limited information from the patient perspective. Despite the chronic nature of hydrocephalus, there is limited infrastructure for the collection of longitudinal data, especially for the quality of life from the patient perspective.

In response to these gaps, the Hydrocephalus Association developed the Hydrocephalus Association Patient-Powered Interactive Engagement Registry (HAPPIER). This survey-based patient registry allows for the collection of a wide range of data relating to the life course and experiences of those with hydrocephalus. Three primary goals guided the conception of HAPPIER: (1) to provide investigators and clinicians with disease symptoms from a patient perspective, current treatment practices, and patient-centered outcomes to better guide therapeutic interventions; (2) to track the characteristics and experiences of those living with hydrocephalus over time; and (3) to identify patients potentially eligible for research studies and/or clinical trials. The registry also provides a readily accessible population to develop other survey-based studies. This article reports the initial findings on the demographics and characteristics of the HAPPIER registry population.

Methods

Design

A 10-member steering committee composed of Hydrocephalus Association staff, scientists and medical professionals in the field of hydrocephalus, persons living with hydrocephalus, and caregivers of those with hydrocephalus was formed in 2015. The committee studied registries with similar goals, such as the Interactive Autism Network[13] and Cystic Fibrosis Foundation Patient Registry Data,[14] along with other surveys and assessments, including the NINDS Quality of Life in Neurological Disorders (Neuro-QoL),[15] NIH Patient-Reported Outcomes Measurement Information System (PROMIS),[16] 15D Quality of Life Questionnaire,[17] National Alzheimer's Coordinating Center (NACC) Functional Activities Questionnaire (FAQ),[18] Katz Index of Independence in Activities of Daily Living,[19,20] Lawton-Brody Instrumental Activities of Daily Living Scale (I.A.D.L).,[21] Pediatric Quality of Life Inventory,[22] and Hydrocephalus Outcome Questionnaire.[23] The faculty at the University of Utah Data Center and other experts also provided input. These sources informed the development of HAPPIER. The steering committee took particular care to ensure that the survey was understandable.

The Hydrocephalus Association developed the web-based Hydrocephalus Association Patient Portal for participants to access and enter the registry. The University of Utah managed and collected data from participants over the age of 18 and from caregivers using a REDCap database instance. REDCap is a platform designed for data capture, management, and collection pertaining to surveys, databases, trials, applications, questionnaires, registries, quality reviews, and various types of research studies.[24]

Ethics Statement

The University of Utah Institutional Review Board (IRB) approved the study in May 2017. The study was approved for exemption status because it poses minimal risk, is in accordance with the Belmont Report, complies with the principles stated in the Declaration of Helsinki, and contains orderly monitoring and accounting of research activities. Upon entry into the portal, registrants accessed a consent letter providing them with information about filling out the surveys and the contact information of the study investigators. Only patients over the age of 18 years old with the ability to provide consent took the survey for themselves. For patients under the age of 18 years old, or patients who had impaired ability to provide consent, caregivers filled out the surveys in their stead. REDCap stores all the data. The server facility was located separately from the remainder of the Data Center at the University of Utah. Researchers de-identified all datasets used for analysis.

Recruitment

The Hydrocephalus Association developed social and traditional media for participant recruitment, including emails, posts on Facebook, Twitter, and Instagram, printed newsletters, and direct mail. Additionally, the Hydrocephalus Association advertised HAPPIER on its website and at community-centered conferences and fundraising events. Medical professionals also referred patients to join HAPPIER. All potential participants accessed the Hydrocephalus Association Patient Portal for more information and instructions to join the registry.

Analysis

HAPPIER launched on June 29, 2018. The dataset for this analysis consisted of responses to the baseline survey (Supplemental File 1), retrieved on March 8, 2022. The registry recorded the demographic makeup, hydrocephalus etiology, and treatments received by participants. Survey responses captured information on comorbidities, symptom categories, and treatment history, which the analysis presented as percentages of the overall registry population. The analysis also calculated the percentage of participants who underwent shunt and/or ETV revision surgery and who experienced shunt infection. Finally, it determined the retention rate for the longitudinal arm of the registry.

Data Access Statement

To obtain data from the HAPPIER registry to conduct a study, or to use HAPPIER to distribute a new survey, please email the Hydrocephalus Association National Director of Research (research@hydroassoc.org).

Results

A total of 691 people participated in the HAPPIER registry and completed the baseline survey (Supplemental File 1). Participants refer to the individuals with hydrocephalus represented in the survey data, both those who recorded their own responses and those for whom a caregiver answered on their behalf. The HAPPIER registry captures demographic information for all participants (Table 1). 65.3% of the participants were persons living with hydrocephalus and completed the surveys for themselves, and 34.7% had a caregiver complete the surveys in their stead. The data represented all ages including infants (0–11 months, 5.8%), toddlers (1–3 years, 9.1%), children (4–12 years, 9.0%), teenagers (13–17 years, 3.9%), young adults (18–34 years, 32.1%), adults (35–59 years, 27.4%), and older adults (60+ years, 12.7%). A majority of participants were female (55.0%), and males represented 44.3%. An additional 0.7% either preferred not to answer or identified as transsexual.

The participants predominantly identified their race as white (86.0%). Black or African American participants accounted for 4.5% of the participants, Asian, 2.6%, American Indian or Alaska Native, 1.0%, or other, 4.8%. The

Table 1 Demographics

Demographics	Participants n (%)
Total	691 (100)
Survey Completed By	
Self	451 (65.3)
Caregiver	240 (34.7)
Parent caregiver*	209 (87.1)
Child caregiver*	7 (2.9)
Spouse caregiver*	13 (5.4)
Other caregiver*	11 (4.6)
Age at time of survey	
Infant (0–11 months)	40 (5.8)
Toddler (1–3 years)	63 (9.1)
Child (4–12 years)	62 (9.0)
Teenager (13–17 years)	27 (3.9)
Young Adult (18–34 years)	222 (32.1)
Adult (35–59 years)	189 (27.4)
Older Adult (60+ years)	88 (12.7)
Gender	
Female	380 (55.0)
Male	306 (44.3)
Transsexual	2 (0.3)
Prefer not to answer	3 (0.4)
Race	
White or Caucasian	594 (86.0)
Black or African American	31 (4.5)
Asian	18 (2.6)
American Indian or Alaska Native	7 (1.0)
Other	33 (4.8)
Prefer not to answer/Unknown	8 (1.2)
Ethnicity	
Not Hispanic or Latino	516 (74.7)
Hispanic or Latino	68 (9.8)
Ashkenazi Jewish	25 (3.6)
Prefer not to answer	47 (6.8)
Unknown	35 (5.1)
Country of Residence	
United States of America and Territories	606 (87.7)
United Kingdom	18 (2.6)
Canada	17 (2.5)
Australia	14 (2.0)
Other	35 (5.1)
Prefer not to answer	1 (0.1)

Note: *Percentage is out of Caregiver count.

participants indicated their ethnicities as follows: not Hispanic or Latino (74.7%), Hispanic or Latino (9.8%), Ashkenazi Jewish (3.6%), preferred not to answer (6.8%), or selected "unknown" (5.1%). Most participants resided in the United States or its territories (87.7%). Participants living in the United Kingdom, Canada, and Australia made up 7.1% of the registry. The remaining participants were from countries including Argentina, Bahamas, Belgium, Denmark, Egypt, France, Germany, Hungary, India, Ireland, Israel, Jordan, Kenya, Nepal, Netherlands, New Zealand, Norway, Philippines, Portugal, Russia, South Africa, Turkey, Uruguay, and Zimbabwe.

The survey captured participants' hydrocephalus-specific characteristics (Table 2 and Figure 1). Most participants were diagnosed before the age of one, as infants (0–11 months) or prenatally (58.9%). Others were diagnosed in the following years: toddler (1–3 years, 4.1%), child (4–12 years, 5.6%), teenager (13–17 years, 3.6%), young adult (18–34 years, 8.5%), adult (35–59 years, 9.4%), older Adult (60+ years, 8.7%), and 1.2% answered "unknown/unsure". Participants reported many types of causes of hydrocephalus, which were divided into the major categories of congenital hydrocephalus (43.8%), acquired hydrocephalus (27.1%), idiopathic normal pressure hydrocephalus (iNPH) (14.2%), unknown/unsure (14.8%), and prefer not to answer (0.1%) (Table 2). The top reported subcategories of congenital hydrocephalus included those who reported unknown/unsure (32%), aqueductal stenosis (26.1%), and idiopathic hydrocephalus (18.2%). The top reported subcategories of acquired hydrocephalus included posthemorrhagic hydrocephalus of prematurity (PHHP, 33.2%), brain tumor (15.0%), and infection (13.4%).

Table 2 Hydrocephalus Characteristics

Hydrocephalus Characteristics	Participants n (%)
Total	691 (100)
Age at Diagnosis	
Prenatal	88 (12.7)
Infant (0–11 months)	319 (46.2)
Toddler (1–3 years)	28 (4.1)
Child (4–12 years)	39 (5.6)
Teenager (13–17 years)	25 (3.6)
Young Adult (18–34 years)	59 (8.5)
Adult (35–59 years)	65 (9.4)
Older Adult (60+ years)	60 (8.7)
Unknown/Unsure	8 (1.2)
Etiology	
Congenital Hydrocephalus	303 (43.8)
Aqueductal Stenosis*	79 (26.1)
Idiopathic*	55 (18.2)
Dandy Walker Formation*	16 (5.3)
Spina bifida/Myelomeningocele*	12 (4.0)
Arachnoid Cyst*	8 (2.6)
Chiari Malformation*	7 (2.3)
X-Linked (L1 Syndrome)*	4 (1.3)
Craniosynostosis*	2 (0.7)
Encephalocele*	2 (0.7)
Midbrain Tumor or Lesion*	2 (0.7)
Other*	16 (5.3)
Prefer not to answer*	2 (0.7)
Unknown/Unsure*	97 (32.0)
Acquired Hydrocephalus	187 (27.1)
Posthemorrhagic Hydrocephalus of Prematurity (PHHP)$^{+}$	62 (33.2)
Brain Tumor^{+}	28 (15.0)
Infection^{+}	25 (13.4)
Hemorrhage^{+}	17 (9.1)
Head Injury^{+}	15 (8.0)
Other^{+}	27 (14.4)
Unknown/Unsure^{+}	13 (7.0)
Idiopathic Normal Pressure Hydrocephalus (iNPH)	98 (14.2)
Prefer not to answer	1 (0.1)
Unknown/Unsure	102 (14.8)

(*Continued*)

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Table 2 (Continued).

Hydrocephalus Characteristics	Participants n (%)
Treatment(s)	
Shunt(s) Only	492 (71.2)
Unsure or prefer not to answer if also treated with ETV~	55 (11.2)
ETV (with or without CPC) Only	47 (6.8)
ETV, unsure if also treated with shunt^	1 (2.1)
Shunt(s) and ETV (with or without CPC)	86 (12.4)
Not Treated with Shunt(s) nor ETV (with or without CPC)	62 (9.0)
No shunt, unsure of ETV#	4 (6.5)
No ETV, unsure of shunt#	4 (6.5)
Unknown/Unsure	4 (0.6)

Notes: *Percentage is out of Congenital Hydrocephalus count. +Percentage is out of Acquired Hydrocephalus count. ~Percentage is out of Shunt(s) Only count. ^Percentage is out of ETV (with or without CPC) Only count. #Percentage is out of Not Treated with Shunt(s) nor ETV (with or without CPC) count.
Abbreviations: ETV, endoscopic third ventriculostomy; CPC, choroid plexus cauterization.

Shunt placement ranked as the most prevalent treatment (Table 2). 492 (71.2%) participants received treatment with shunt(s) only. Of these 492 participants, 55 (11.2%) were unsure or preferred not to answer if they had also been treated with an endoscopic third ventriculostomy (ETV). Other participants reported only being treated with an ETV (with or

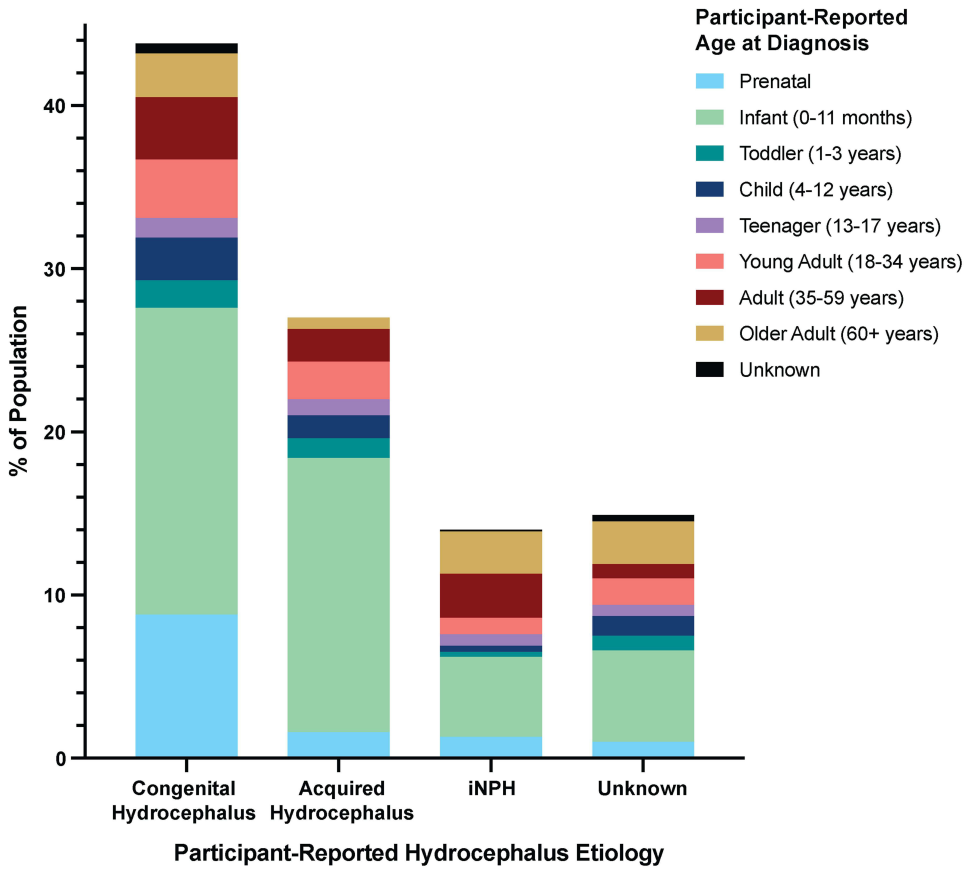

Figure 1 Participant-Reported Hydrocephalus Etiology and Age at Diagnosis. Data are self-reported from patients or their caregivers, and not based on data from medical professionals. The age of diagnosis breakdown for congenital hydrocephalus, acquired hydrocephalus, idiopathic normal pressure hydrocephalus (iNPH), and unknown/unsure or prefer not to answer etiologies is displayed. The highest number of participants (43.8%) had congenital hydrocephalus, with 42.3% of this group reported being infants at the age of diagnosis.

without CPC) (6.8%). The remaining participants reported being treated with shunt(s) and ETV (with or without CPC) (12.4%), neither treatment (62 participants, 9.0%), or were unsure or did not know of their treatment (0.6%). Of the 62 participants who had not been treated with shunt(s) nor ETV (with or without CPC), 8 participants (13%) were not completely sure of their treatment history.

Participants also reported their treatment complications (Figure 2). Of the 578 participants who were treated with a shunt(s) (including those with shunt(s) and ETV), 399 (69.0%) of them had at least one shunt revision, and 138 (23.9%) of them had at least one shunt infection. Of the 133 participants who were treated with an ETV (with or without CPC) (also including those with shunt(s) and ETV), 46 (34.6%) of them reported receiving at least one ETV revision. Among those who experienced an ETV revision, 69.6% had 1 revision, 23.9% had 2–4 revisions, and 6.5% had 5 or more revisions.

Participants reported their symptoms (Figure 3). The three most frequently reported symptoms were headaches (60.3%), tiredness/lethargy (55.4%), and memory problems (47.6%). Participants also reported their diagnosed comorbidities, which were grouped into the following general categories: movement impairments, emotional disorders, cognitive disorders, educational disorders, and other diagnosed health conditions (Figure 4). 69.9% of the survey population had reported movement impairments including tremors, ticks, and other stereotyped movements, or difficulty with balance and walking. 44.7% of registrants reported being diagnosed with emotional disorders, including depression, anxiety, and/or OCD. 42.5% of the registrants reported cognitive disorder diagnoses, including ADHD, autism, receptive delay, expressive delay, executive function disorder, global developmental delay, intellectual disability, visual processing deficits, and short-term memory

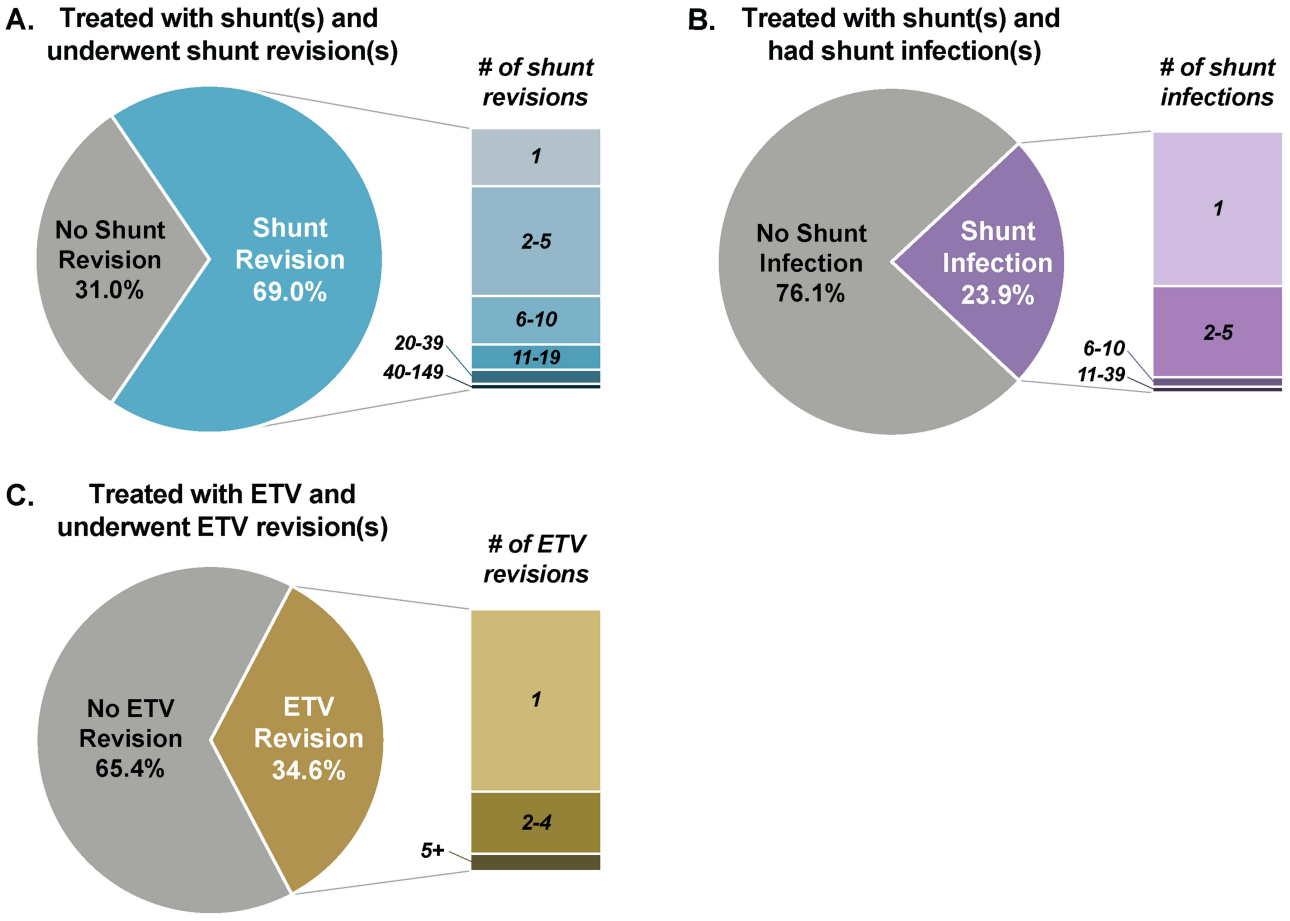

Figure 2 Treatment Complications. Displays the percentage of participants treated with shunt(s) and (**A**) underwent shunt revision(s) or (**B**) had shunt infection(s), and the percentage of participants treated with ETV that (**C**) underwent ETV revision(s), along with the number of shunt revisions, shunt infections, and ETV revisions participants have had, respectively. Those treated with shunt(s) include all participants treated with shunt(s) only or shunt(s) and ETV (with or without CPC). Those treated with ETV include all participants treated with ETV (with or without CPC) only or shunt(s) and ETV (with or without CPC). Shunt revisions were the most common treatment complication.

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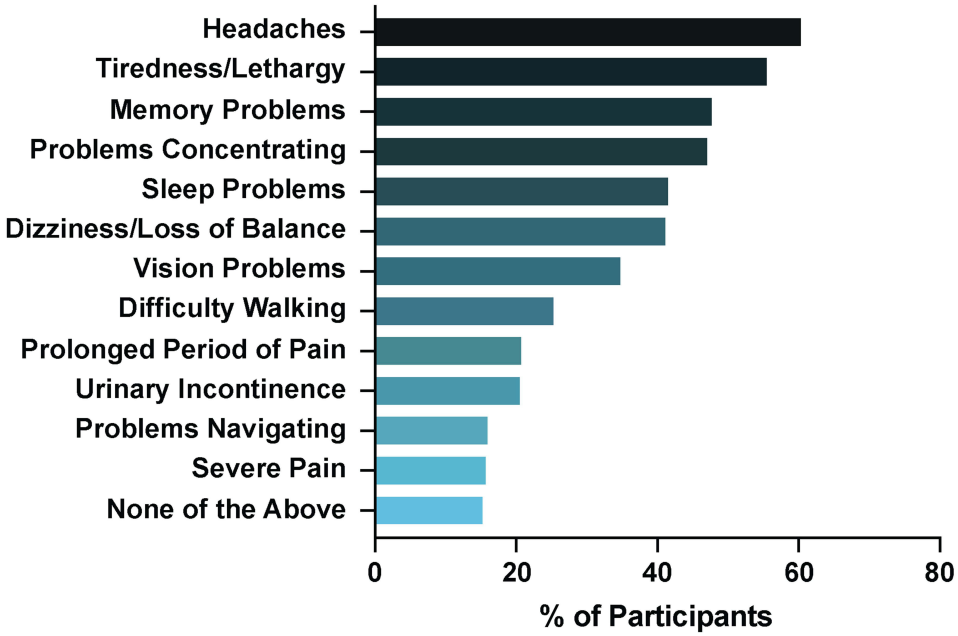

Figure 3 Symptoms Profile. Displays the percentage of participants experiencing symptoms most associated with hydrocephalus. Headaches, tiredness/lethargy, and memory problems were the most frequently reported symptoms.

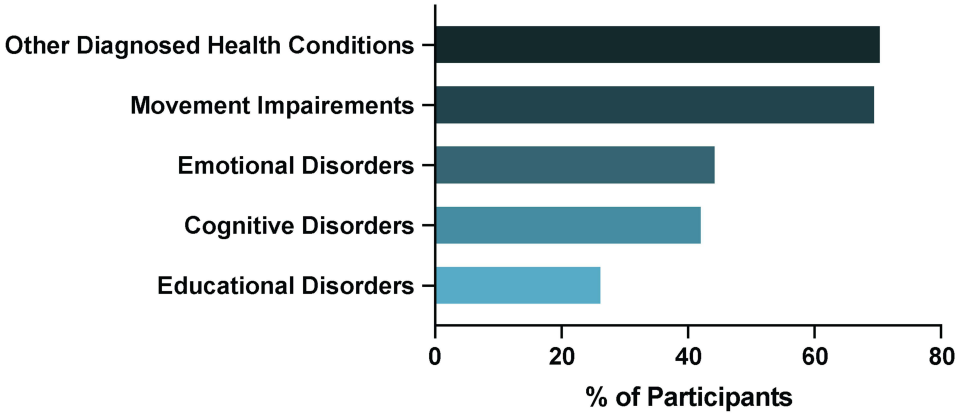

Figure 4 Diagnosed Comorbidities. Displays the percentage of participants experiencing other diagnosed health conditions, impairments, or disorders alongside hydrocephalus.

problems. 26.6% of registrants reported educational disorder diagnoses, including learning disabilities in math, reading, and/or writing and non-verbal learning disabilities. 70.8% received a diagnosis for at least one other diagnosed health condition, aside from hydrocephalus, with the top three most prevalent conditions being visual impairment, migraine, and chronic pain. Other conditions within this category include epilepsy, cerebral palsy, Chiari malformation, spina bifida, sleep apnea, diabetes, obesity, hypertension, and various dementias, amongst others.

One of the goals of HAPPIER is to collect longitudinal data. Between 2018 and 2020, 618 participants joined HAPPIER and completed the baseline survey (Supplemental File 1). Of this population, 35% continued with the longitudinal arms and completed the 2021 Annual Survey.

Discussion

The Hydrocephalus Association created HAPPIER to capture the perspectives, experiences, and outcomes of patients with hydrocephalus to address a significant gap in patient-centered data in hydrocephalus research. The registry collects

data on measures not typically found in medical records, such as quality of life measures, over time, as these outcomes have been historically lacking. The purpose of this initial publication is to present an overview of the composition of the registry, highlighting the demographics of the participants, the etiology of hydrocephalus, treatments, complications, symptom profiles, and comorbidities.

The initial participation from 691 people indicates that the hydrocephalus patient community wants to share their information with the medical and scientific communities. The data captured from all different age ranges, from newborns through older adults (up to 90 years old), emphasize the desire for a wide range of patients and caregivers to participate in research and contribute their perspectives. The racial demographics of the HAPPIER registry, with 86.0% of participants identifying as white, present a discrepancy compared to observed national hydrocephalus data[25–27] which demonstrate a more diverse patient population. This underrepresentation underscores the need for targeted efforts to increase diversity within the HAPPIER dataset to accurately reflect the broader hydrocephalus community and further support equitable research and care.

To address the current lack of diversity in the HAPPIER registry, the Hydrocephalus Association is developing targeted outreach strategies to support more inclusive future recruitment. These efforts include geo-targeted campaigns informed by national census data to identify underrepresented regions and communities. The Association plans to prioritize outreach to hospitals and clinics that serve Indigenous populations, lower-income groups, and historically marginalized communities. It also aims to collaborate with medical and professional societies to increase awareness of HAPPIER among providers who care for diverse populations. Furthermore, the Association will expand engagement with diverse audiences through direct outreach on social media platforms, including targeted messaging to individuals already connected with the organization. In addition, the Hydrocephalus Association intentionally features diverse individuals in its marketing and outreach materials to reflect the inclusivity of the hydrocephalus community and encourage broad participation. Together, these strategies aim to improve representation across race, ethnicity, gender, socioeconomic status, and disease experience, strengthening the registry's utility in informing equitable, patient-centered research and care.

Moreover, the initial registry, created in 2018, included limited gender options: "male", "female", "transexual", and "prefer not to answer". At the time of data retrieval, 2 participants identified as transexual, and 3 selected prefer not to answer. Given the restricted choices, it is possible that participants may have responded differently had more inclusive options, such as those now available, been provided in the original survey. The Hydrocephalus Association has since updated the HAPPIER survey options for gender identity, modeled after the NIH's All of Us Program categories, to include "male", "female", "non-binary", "transgender", "prefer not to answer", and an area to list their own description.

In addition to capturing demographic information, an important aspect of the registry is that it sheds light on the multifaceted health challenges faced by participants, some of which are not typically captured during medical visits. These patient-reported symptoms and comorbidities highlight the complex experiences of those living with hydrocephalus. This suggests that available treatments do not adequately address motor, cognitive, developmental, and neuropsychiatric difficulties present with hydrocephalus. Furthermore, seeing as 9.0% of registrants were not treated with a shunt nor an ETV, it is worth investigating this subset of the population further to see if these individuals represent a group that needs treatment but is not being treated.

A vast majority of the surveyed population had at least one other diagnosed health condition in addition to hydrocephalus (70.8%). Among those living with iNPH, those with multiple comorbidities report having worse hydrocephalus symptoms prior to any operation, especially regarding gait and balance performance.[28] These comorbidities can also worsen the prognosis of the condition and of CSF shunting.[29] Patients with comorbidities may require a different approach to treatment than those without,[29] and HAPPIER results suggest that the percentage of patients falling in this category is substantial. Furthermore, by reporting data on which symptoms are present among the highest percentage of registrants, as shown in Figure 3, HAPPIER captures information that could be beneficial in future research to determine potential new treatments to target the most prevalent symptoms.

The etiology breakdown among HAPPIER participants provides insights alongside the current literature. A survey that collected data from 683 children and adults with hydrocephalus in a neurosurgical center over five years found that 30.8% had hydrocephalus that stemmed from a congenital malformation and 8.9% had NPH.[30] In contrast, a study that extracted hospital admissions data from the Healthcare Cost and Utilization Project (HCUP), National Inpatient Sample (NIS), Agency for Healthcare Research and Quality (AHRQ), and Kids' Inpatient Database (KID) reported that 8.0% of

hydrocephalus etiology hospital admissions were for congenital hydrocephalus.[26] Another study of 1000 individuals aged 65+ in Sweden reported a prevalence rate of 3.7% for iNPH.[31] Discordantly, our data report a higher figure for both congenital hydrocephalus (43.8%) and iNPH (14.2%). These varying numbers may reflect our recruitment methods, which included targeting community network support groups, potentially skewing the data toward these populations. This indicates a need to increase recruitment efforts and diversity the registry to ensure it properly represents all etiologies and reflects the national averages.

Similarly, these disparities may be due to the self-reporting nature of the patient registry and potential misinformation about what type of hydrocephalus the participant has. Since HAPPIER is not based on clinical data from medical professionals, the data reveal that a considerable number of hydrocephalus caregivers and patients have substantial knowledge gaps and uncertainty, particularly regarding hydrocephalus etiology. Notably, 14.8% of HAPPIER participants did not know or were not sure of the type of hydrocephalus they had. Furthermore, 32.0% of those with congenital hydrocephalus and 7.0% of those with acquired hydrocephalus were unaware of the cause of their condition. Surprisingly, the vast majority (80.6%) of participants who reported an iNPH diagnosis recorded that they were diagnosed under the age of 60 (eg as infants or young adults), and 18.4% over the age of 60 (Figure 1). This reveals that participants had a great misunderstanding of what iNPH is. iNPH primarily affects those 65 and older.[32] Their misunderstanding may have stemmed from their interpretation that if their hydrocephalus is well-controlled and "normal", they have "normal" pressure hydrocephalus. Taken together, these data reveal that a substantial number of participants may lack knowledge about their overall medical profile, which could lead to more difficulty accessing treatment and advocating for themselves. This demonstrates a great need for better patient education, underscoring the value of patient-reported registries, which can capture insights directly from patients and their caregivers, addressing gaps in understanding and highlighting unmet needs.[32]

One potential solution to this lack of patient knowledge is HydroAssist®, an app designed to help individuals track their hydrocephalus history and better manage their condition (www.HydroAssoc.org/HydroAssist). Additionally, the Hydrocephalus Association is implementing several strategies to improve the accuracy of self-reported data. Planned updates will introduce conditional logic to key survey items to reduce common misclassifications—for example, limiting the option to select iNPH to participants over age 60. Additional follow-up prompts and clearer, lay-friendly definitions will further support participant understanding and accuracy. Participants will also have the option to revise their baseline response regarding hydrocephalus etiology as they receive additional education or updated diagnoses from their physicians. A future avenue for exploration includes linking registry data with electronic medical records to enhance data validation and complement patient-reported responses. For analyses where self-reported variables are known to be error-prone, we will employ sensitivity analyses, use broader or aggregated categories (eg, grouping etiologies as congenital, acquired, or unknown), and exclude or flag implausible entries when appropriate. These efforts aim to balance data integrity with participant autonomy, ultimately strengthening the reliability and utility of HAPPIER data for research and clinical insight.

Identifying the unmet needs of patients can help guide changes in both clinical practice and research focus. For example, the Hydrocephalus Association conducted a formalized survey study, collecting responses from patients and family members, as well as scientists and physicians working in hydrocephalus, to determine key priorities in hydrocephalus research.[33] These responses directly informed the creation of the Hydrocephalus Association's community research priorities,[33] which now guide their research initiatives and strategic plans. This highlights the critical role that patient-reported data plays in driving meaningful advancements in research, ensuring that efforts align with the real-world needs and concerns of the hydrocephalus community.

The HAPPIER registry offers a unique view of the population of people living with hydrocephalus, however, there are some limitations of the data. The recruitment methods may have biased the sample toward individuals more heavily impacted by the condition, as this population engages more frequently with the Hydrocephalus Association, which handled most of the recruitment. The Hydrocephalus Association advertised for patients or their caregivers to sign up for the registry and take the surveys. Future studies conducted using HAPPIER data will consider how to implement targeted recruitment of the groups missing in this initial population in terms of disease impact, as well as demographic factors, such as race and ethnicity. Additionally, as either caregivers or patients can enter the registry, there is a risk of duplicative

data if both enter the registry. The Hydrocephalus Association is developing software and data strategies to reduce the risk of analyzing duplicative data and is designing studies to compare the matched caregiver and patient responses.

A goal of this registry to collect longitudinal data. A 35% retention rate of engagement in the longitudinal arms indicates that a notable percentage of the initial population demonstrated an interest in continuing to engage in the registry and provide valuable data for longitudinal studies. This noted, the Hydrocephalus Association is creating a marketing and communication strategy to encourage annual compliance after the initial entry to the registry and ensure that this retention rate does not decrease over time. Planned updates to the HAPPIER platform include visual summaries of aggregated survey responses, allowing participants to view data trends and better understand how their input contributes to broader insights. To further boost engagement, the Hydrocephalus Association will share key findings from the surveys with the broader community, complemented by educational webinars that highlight results and promote continued participation. The registry also plans to integrate text messaging capabilities to deliver timely notifications, including links to annual surveys. It aims to leverage this feature for engagement initiatives such as a "question of the month", designed to sustain participant interest and promote year-round involvement. In parallel, the Hydrocephalus Association is exploring the integration of HAPPIER with its existing HydroAssist® app to streamline survey distribution, deliver push notifications, and enhance the overall user experience.

Enrollment to the registry is currently active as well as data collection from these initial participants. Given the recruitment efforts to the registry and the information captured, HAPPIER has great potential as a platform for other scientists to run their own surveys and studies on this registry population. The datasets provided by HAPPIER offer unique insight into those living with hydrocephalus and allow for future investigations to better understand the condition. They have the potential to identify relevant patient-reported outcomes for prospective clinical trials going forward. HAPPIER can also be used in conjunction with other databases or registries, as well as by academic and private institutions, to combine or compare the data acquired with other populations. Data scientists and other hydrocephalus researchers may particularly benefit from comparing HAPPIER results with results from registries that are not self-reported to see how bias may have affected responses. Overall, HAPPIER serves as a data registry for hydrocephalus from the patient perspective, particularly in the United States, as no other registry serves the same purpose.

Conclusion

HAPPIER is a novel tool developed by the Hydrocephalus Association to address the gaps in data and infrastructure on non-clinical outcomes, which are critical to clinical care and to understanding hydrocephalus in its totality. HAPPIER collects information regarding demographics, treatment, medical history, education, and lifestyle, and tracks the changes in these variables annually. Longitudinal studies like these are important to see how reported symptoms and comorbidities, and the shunt and ETV revision frequencies may change over time and with aging. While limitations exist due to its self-reported nature, that methodology allows for this broad scope. The registry establishes a method and a population for researchers to conduct studies of various types by using the currently collected outcomes, distributing newly developed surveys, and potentially connecting clinical trials and eligible patients.

Disclosure

Dr Richard Holubkov reports grants from Hydrocephalus Association, during the conduct of the study; personal fees from Pfizer Inc, outside the submitted work. Dr Abhay Moghekar reports I serve on the Medical Advisory Board of the Hydrocephalus Association, a non-paid position. Dr Jenna Koschnitzky is a current staff member of hydrocephalus device start-up in Rhaeos, outside the submitted work. The authors report no conflicts of interest in this work. This paper has been uploaded to Medrxiv as a preprint: https://www.medrxiv.org/content/10.1101/2024.10.11.24315348v1.

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