Overdrainage in Hydrocephalus: causes, treatment, and prevention - a systematic review

Hiperdrenagem Liquórica na Hidrocefalia: causas, tratamento e prevenção – uma revisão sistemática

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ABSTRACT

Since 1956, numerous shunt devices were designed to treat hydrocephalus. Consequently, overdrainage emerged as a serious complication that predisposes to other diseases. This review aims to describe the factors associated with overdrainage and to analyze the main interventions used in the treatment and prevention of this complication. Articles on the PubMed, BVS, Scielo, EMBASE, SCOPUS, Cochrane and Web of Science databases were selected using as terms: "overdrainage", "complications", "hydrocephalus", "valves", "treatment", "neurosurgery". After applying all exclusion criteria, 19 articles were included. In a study with programmable differential pressure (DP) valves, 26.6% of cases of overdrainage were reported showing improvement in symptoms in 87.5% of cases, after valve pressure readjustments. In classic differential pressure valves, studies report higher complications from overdrainage. The low flow (LF) valves obtained an overdrainage rate of 3.2% and the rate of symptom resolution with gravitational valves was higher than 82%. Surgical treatment of hydrocephalus is based on the implantation of a shunt system, ventricular, neuroendoscopy, or both. There are changes in the shunt systems that try to reduce the overdrainage, which includes valves designed to open at different pressures and anti-siphon devices. Third and fourth generation devices show promises in the treatment and prevention of overdrainage, however, studies should continue to be done to ensure even more efficiency.

Keywords: Glymphatic system; Shunts; Valves; CSF flow
INTRODUCTION

Hydrocephalus is defined as an accumulation of cerebrospinal fluid (CSF) within the cranial cavity, resulting from an increase in production or, more frequently, from obstruction of the pathway or decreased absorption. Before the mid-1950s, hydrocephalus was rarely treated. The poor prognosis was usual, and the patient usually died after extensive nursing care and hospitalization. In 1956, ventricular shunt drastically changed the perspective of hydrocephalus and numerous shunt devices were designed for its treatment. In this way, the chances of survival and the almost normal life expectancy were possible. Even so, CSF ventricular shunt in hydrocephalic patients is generally associated with more complication than any other neurosurgical procedure.

CSF overdrainage is a common complication of inserting a shunt to treat hydrocephalus. This term was previously defined as excessive CSF evacuation from the ventricular system. Currently, overdrainage is defined as a phenomenon where the valve is functioning normally, but it drains more than the physiological quantity for some patients, going beyond the concept that it occurs due to failures in the operation of the valves. However, functional complication represent one of the most frequent problems in patients treated with pediatric and adult shunts. It is not just a child's condition, as it can occur at all ages of life.

This condition can present itself relatively early after the insertion of a ventriculoperitoneal shunt, having been shown in a study that women may be more susceptible than men.

According to Hakim's thesis, overdrainage phenomena occurs depending on the intraventricular pressure, which in patients with a shunt is determined by the operating pressure of the valve. Overdrainage is an important complication and can be temporarily treated by adjusting the valve pressure. However, there may be a need for surgical procedures in case of complication.

Siphoning (siphon effect) is a complication of shunt and has been declared as one of the main causes of overdrainage. Most commonly, it can cause slit ventricle syndrome (SVS) and, less frequently, serious complications may arise. In addition, there may be an accumulation of CSF or blood around the brain. More frequently, benign collections of CSF are observed; however, subdural hematomas are possible and can cause serious damage to the elderly. Symptoms are chronic headaches, nausea, vomiting, and impaired school performance. These clinical presentations range from mild to disabling and, in the most severe cases, can result in multiple admissions and operations.

To solve the problem of overdrainage, several types of valves were created (Table 1). The former ones could have their pressure set in a fixed way in low, medium, or high, and sometimes it was difficult to choose the right pressure for each patient. Differential
pressure valves were the first programmable valves introduced in the 1990s and were initially used in patients with normal pressure hydrocephalus (NPH). Currently, there are numerous types of valves on the market used in clinical practice and around 100 types of valves that have received approval.

As a result of the complications generated by overdrainage, this literature review aims to describe the diseases caused by overdrainage and to analyze the valves and devices used in the treatment and prevention of this complication.

### METHODS

The present study followed the methodological procedures described in the literature, which uses systematic and explicit methods to identify, select and critically evaluate the research already published on the topic, according to the methodology described in Preferred Report Items for Systematic Reviews and Meta-analyses (PRISMA) of Experimental type.
The following guiding question was established: “What are the factors and pathologies related to overdrainage and which valves best prevent this involvement?”. The review was performed on the original articles available in the databases PubMed, Virtual Health Library (BVS), Scielo, EMBASE, Sci Verse Scopus Top Cited (Scopus), Cochrane and Web of Science, and were selected using the terms: “overdrainage”, “complications of hydrocephalus”, ‘shunt valves”, “excessive drainage”, “neurosurgery”, “flow”, “glymphatic system” using the search operator “OR” and “AND”. The terms used were determined based on previous studies on the topic and with the help of the advisors.

The search, carried out by all authors, took place in May and considered articles published from 1978 to 2020. Data extraction was carried out by two people and the conflicts were solved in the best possible way with the help of the advisors, so that the quality of the study was not impaired. A total of 805 publications was found and, as inclusion criteria, were considered articles related to changes in CSF flow, types of hydrocephalus, symptomatology, and complications related to overdrainage, types of devices and valves used in the treatment of hydrocephalus, radiological findings and the possible relationship between the glymphatic system and overdrainage. The deadline was due to technological advances in the treatment of hydrocephalus that have occurred from the late 1970s, such as the use of the endoscope in neurosurgery and improvement of shunt-related materials.

Exclusion filters were applied to articles based on year, language, and articles which were not available in full. Therefore, 343 documents were excluded. The total for analysis of titles and abstracts was 558 articles. At this stage, articles that were not original researches were excluded, in addition to those that were not related to the topic studied or the research question. In the case of duplicated articles in the given databases, these were considered only once. As a criterion for the exclusion of results analysis, in vitro studies were declassified due to low scientific evidence, and the studies whose results were not directly correlated with overdrainage.

The qualitative synthesis consisted of 20 articles. To better illustrate the search and the reasons for exclusion from studies, a flowchart was constructed (Figure 1).

**RESULTS**

Hydrocephalus is described as an abnormal accumulation of CSF in the cerebral ventricles. However, the description is simplified and does not focus on the multifactorial aspect of the disease. In most cases, it has two types: communicating and obstructive. Idiopathic normal pressure hydrocephalus (INPH), which affects the elderly population, is a treatable condition, first described by Hakim in 1965. It presents a typical clinical triad, consisting of gait and balance disorders, dementia, and urinary incontinence and it is believed to be responsible for about 5 to 6% of all cases of dementia.

Recently, findings suggest that INPH is a complex disorder of cerebral blood flow and possibly senescent changes in CSF physiology rather than problems in production and absorption.

Hydrocephalus is one of the main disorders of cerebral hydrodynamics in adults. Surgical treatment is based on the implantation of a ventricular shunt system (peritoneum, atrium, or pleural cavity), neuroendoscopy, or both treatments, offering a significant improvement with regards to neurological aspects. In obstructive hydrocephalus, may be recommended the endoscopic third ventriculostomy (ETV), a surgical opening created in the third ventricle that allows CSF flow directly to basal cisterns, a shortcut to any obstruction.

Forty-six studies were identified, but those that did not have results directly related to overdrainage and in vitro tests were excluded from the analysis, resulting in 19 studies. The follow-up time for patients varied between 9 and 39 months. The main symptoms and disturbs related to overdrainage were subdural effusions, SVS, and headaches. The main interventions reported were the programmable differential pressure valve and the gravitational valve. Nineteen of the analyzed studies are included in Table 2.

The placement of programmable differential pressure valves, with or without an anti-siphon device, has been reported in eight studies. Rohde et al., in a series of cases with 60 patients, reported 16 cases of excessive drainage (26.6%). Valve pressure readjustment improved symptoms in fourteen cases (87.5%) after the insertion of a programmable DP valve. One study showed that the number of symptomatic cases of overdrainage was drastically reduced after the insertion of a programmable DP valve. The initial valve pressure, when low, caused significantly more symptoms of overdrainage than higher pressure settings in two studies. Even after the implantation of antisiphon devices and gravitational units, there was a need for pressure readjustment, as demonstrated by some prospective and retrospective studies. A significant relation (P < 0.001) was also found between congenital hydrocephalus and predisposition to the excessive drainage.
In relation to classic differential pressure valves, three of the analyzed studies had compared their effectiveness with low flow and gravitational valves, and the results obtained were unfavorable to their placement, as they demonstrate relatively greater risks of complications due to overdrainage\textsuperscript{33,36,41}. About LF valves, Wetzel et al. obtained an overdrainage rate of 3.2\% in the study\textsuperscript{27}.

Gravitational valves had a symptom resolution rate above 82\% in three studies, with readjustments over the follow-up period\textsuperscript{32,37,38}. Alvarado et al. demonstrated considerable improvement (P < 0.0001) of postural headache after implantation of the gravitational valve\textsuperscript{10}.

In a cohort study involving two groups (DSV = distal slit valve and ASD = antisiphon device), the incidence of overdrainage was compared. It resulted in a statistically insignificant difference (P > 0.05), meaning that the use of the anti-siphon device was not sufficient to prevent the symptoms of overdrainage\textsuperscript{3}. However, other studies have shown that the use of ASD is effective in preventing overdrainage, with significant differences (P < 0.001) in relation to patients who do not use the device\textsuperscript{29}.

Lemcke et al. compared two groups of patients with gravitational valves and standard programmable valves. After a 6-months follow-up, the incidence of signs and symptoms of overdrainage in the gravitational valve group was reported in five patients of

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*Figure 1. Flowchart: represent identification, screening, eligibility and inclusion and exclusion criteria in the review.*
Table 2. Key results of studies on different interventions.

<table>
<thead>
<tr>
<th>Study</th>
<th>Type of study</th>
<th>Study location</th>
<th>Number of patients and intervention</th>
<th>Age</th>
<th>Key points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alvarado et al., 2017</td>
<td>Retrospective study</td>
<td>England</td>
<td>NP = 20 I = Gravitational valve</td>
<td>24.5 years (Range 4-53)</td>
<td>Postural headache was significantly improved (P &lt; 0.0001) in the patients with gravitational valve. The symptoms related to INPH improved significantly (P &lt; 0.05) and the overdrainage rate was 3.2%.</td>
</tr>
<tr>
<td>Wetzel et al., 2018</td>
<td>Prospective study</td>
<td>Germany</td>
<td>NP = 32 I = Low flow valve</td>
<td>71.2 years (Range 55-84)</td>
<td>16 shunted patients had clinical signs of CSF overdrainage. In 14, the symptoms were improved by readjustment of the valve pressure settings.</td>
</tr>
<tr>
<td>Rohde et al., 1998</td>
<td>Case series</td>
<td>Germany</td>
<td>NP = 60 I = Programmable differential pressure valve</td>
<td>3.4 years (Range 0-14)</td>
<td>General complication rate was significantly improved (P &lt; 0.001) after the implantation of an ASD if compared with shunted patients without ASD; 81% of the 120 patients remained free of SVS symptoms.</td>
</tr>
<tr>
<td>Gruber et al., 2010</td>
<td>Cohort study</td>
<td>Germany</td>
<td>NP = 54/66 I = Antisiphon device</td>
<td>Range: 0-2 years</td>
<td>Seven patients were reoperated due to CSF overdrainage. The overall neurological symptoms improvement was 76%.</td>
</tr>
<tr>
<td>Pinto et al., 2020</td>
<td>Cohort study</td>
<td>Brazil</td>
<td>NP = 112 I = Fixed-pressure valve with antisiphon device</td>
<td>Range: 19-90 years</td>
<td>The amount of symptoms related to overdrainage was not significantly different between DSV and ASD groups (P &gt; 0.05).</td>
</tr>
<tr>
<td>Virella et al., 2002</td>
<td>Cohort study</td>
<td>United States</td>
<td>NP = 101/40 I = Distal slit valve, antisiphon device</td>
<td>Range: 0-17 years</td>
<td>The incidence of overdrainage was 17% in the DP group and 3.7% in the LF group.</td>
</tr>
<tr>
<td>Jain et al., 2000</td>
<td>Cohort study</td>
<td>United Kingdom</td>
<td>NP = 27/23 I = Differential pressure valve, low flow valve</td>
<td>26.4 months (Range 0-16)</td>
<td>The incidence of overdrainage was 17% in the DP group and 3.7% in the LF group.</td>
</tr>
<tr>
<td>Freimann et al., 2012</td>
<td>Retrospective study</td>
<td>Germany</td>
<td>NP = 250 I = Programmable differential pressure valve with gravitational unit</td>
<td>56.2 years</td>
<td>After a median 2.1-year follow-up, overdrainage was related in 39 (15.6%) patients. In all 39 overdrainage cases, the readjustment of the valve pressure was made one (27), two (8), or three (4) times and no recurrences were observed.</td>
</tr>
<tr>
<td>Kehler et al., 2015</td>
<td>Prospective multicenter study</td>
<td>Germany</td>
<td>NP = 120 I = Gravitational valve</td>
<td>38.5 years (Range 0-89)</td>
<td>The overall resolution rate was 87%. Revision of the valve was made in 3 patients due to overdrainage.</td>
</tr>
<tr>
<td>Bozhkov et al., 2017</td>
<td>Retrospective study</td>
<td>United States</td>
<td>NP = 21/19 I = Differential pressure valve, low flow valve with antisiphon device</td>
<td>DP group: 74 years ASD: 73.3 years</td>
<td>The difference in overdrainage cases was not statistically significant (P = 0.083), despite the number of cases in the DP group (3) and the ASD group (0).</td>
</tr>
<tr>
<td>Rohde et al., 2009</td>
<td>Cohort study</td>
<td>Germany</td>
<td>NP = 53 I = Programmable differential pressure valve with gravitational unit</td>
<td>7.3 years (Range 0-17)</td>
<td>During a 15.2-month follow-up, the opening pressure was changed in 8 patients due to overdrainage.</td>
</tr>
<tr>
<td>Saehle et al., 2014</td>
<td>Prospective double-blinded, randomized, controlled, dual-center study</td>
<td>Sweden</td>
<td>NP = 34/34 I = Programmable differential-pressure valve</td>
<td>71 years (Range 50-89)</td>
<td>Seven patients presented with overdrainage symptoms. The valve settings in ≤ 12 cmH2O caused significantly more overdrainage symptoms if compared to the settings in &gt; 12 cmH2O (P = 0.016).</td>
</tr>
<tr>
<td>Lemcke et al., 2010</td>
<td>Prospective study</td>
<td>Germany</td>
<td>NP = 24 I = Programmable differential-pressure valve with antisiphon device</td>
<td>68 years (Range 32-85)</td>
<td>Overdrainage was observed in 3% of the patients.</td>
</tr>
<tr>
<td>Suchorska et al., 2015</td>
<td>Cohort study</td>
<td>Germany</td>
<td>NP = 49/40 I = Gravitational valve, differential-pressure valve</td>
<td>73.5 years</td>
<td>The risk of hygroma as a sign of overdrainage was significantly higher (P &lt; 0.05) in the DP group.</td>
</tr>
<tr>
<td>Wetzel et al., 2019</td>
<td>Cohort study</td>
<td>Germany</td>
<td>NP = 49/38 I = Low flow valve, differential pressure valve</td>
<td>72 years (Range 53-87)</td>
<td>The difference of subdural effusions as a sign of overdrainage, between the DP group and LF was significant (P = 0.002).</td>
</tr>
<tr>
<td>Weinzierl et al., 2012</td>
<td>Retrospective study</td>
<td>Germany</td>
<td>NP = 17 I = Gravitational valve</td>
<td>7 years (Range 2-15)</td>
<td>In the majority patients (14), overdrainage symptoms were improved.</td>
</tr>
<tr>
<td>Tschan et al., 2013</td>
<td>Cohort study</td>
<td>Germany</td>
<td>NP = 55 I = Gravitational valve</td>
<td>15.5 years</td>
<td>91% of the patients reported resolution of the overdrainage symptoms. During one-year follow-up period, 136 readjustments were performed.</td>
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Ventricular shunt

In 1949, Nulsen and Spitz started a modern era of shunting by inserting a pressure-responsive one-way valve into the ventricular shunt system. Since the 1950s, more than 100 valves of different types have been built to improve the drainage system\(^3\). Most of them are available with high, medium, or low-pressure configurations. CSF shunt has benefited countless hydrocephalic patients\(^28,42\). Shunt dysfunctions can occur occasionally and are divided into three groups: “Mechanical” – failure related to the malfunction of the device and includes obstructions, disruptions, and disconnections; “Infection” – related to the colonization of the catheter or the valve implanted in the body and the development of clinical infection in the CSF within the shunt or the tissue around it; and “Functional” – related to the hydrodynamic properties of the shunt\(^30\).

Shunt valves

The valves have been divided into generations according to their structures, starting with the fixed pressure valves (first generation). They are programmed only once and can have low, medium, or high pressure. It is important to note that each valve manufacturer has its specific pressure levels. This generation is represented by the Sphera and Sphera Duo valves, which have an anti-siphon mechanism to prevent overdrainage\(^24,25,43,44\).

The second generation represents the differential pressure valves with anti-siphon device/programmable differential pressure valves. This generation is represented by valves such as Delta and CHPV\(^43-45\).

Subsequently, emerged the third generation with the programmable differential pressure valves with an anti-siphon device. Its pressure can be adjusted several times in a non-invasive way, using magnetic devices. This generation is represented by valves such as proGAV and Codman Hakim Programmable Valve with SiphonGuard (CHPV-SG)\(^34,40,44\).

The fourth generation is composed of valves with a programmable anti-siphon device. This generation is the most recent and has an efficient siphoning control system. Therefore, it is the most effective in the treatment and prevention of overdrainage. However, it has a higher cost than other valves. An example is the proSA gravitational valve\(^32,38,44\).

<table>
<thead>
<tr>
<th>Study</th>
<th>Type of study</th>
<th>Study location</th>
<th>Number of patients intervention</th>
<th>Age</th>
<th>Key points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Delwel et al., 2013</td>
<td>Multicentre prospective randomized trial</td>
<td>The Netherlands</td>
<td>NP = 30/28 I = Programmable differential pressure</td>
<td>&lt; 85 years</td>
<td>At a 9-month follow-up, subdural effusions as a sign of overdrainage occurred significantly in group 1 (P = 0.043), which had low-pressure settings in the valve.</td>
</tr>
<tr>
<td>Sprung et al., 2010</td>
<td>Cohort study</td>
<td>Germany</td>
<td>NP = 165 I = Programmable differential pressure valve with gravitational unit</td>
<td>63 years (Range 0-84)</td>
<td>After one-year follow-up, overdrainage was detected in 35 patients. The readjustment of the valve pressure settings was capable to improve the symptoms.</td>
</tr>
<tr>
<td>Lemcke et al., 2013</td>
<td>Pragmatic, multicentre, open label, randomized, parallel group trial</td>
<td>Germany</td>
<td>NP = 71/74 I = Programmable valve, gravitational valve</td>
<td>71.9 years (Range 44-83)</td>
<td>At the 6-month follow-up, overdrainage occurred in 29 patients with programmable valves and in 5 patients with gravitational valves (risk difference -36%, 95% CI -49% to -23%; p &lt; 0.001).</td>
</tr>
</tbody>
</table>


DISCUSSION

Through the analysis of the results, it is possible to infer that the best treatment, from the insertion of a shunt, is with the gravity valve. This device stands out both for preventing recurrence and complications of overdrainage, and for being adjustable in a non-invasive way.

Table 2. Continued...
Adjustable shunt valves were introduced to promote optimal drainage of the CSF, based on non-invasive adjustment of the valve pressure. Despite their higher price, they are economical in the sense of avoiding a subset of diversion reviews related to overdrainage. It is recommended to start with a high opening pressure and gradually lower it to reduce the frequency of complications, especially subdural hematoma (SDH). The programmed settings can be changed by external magnetic fields, but there are already valves that resist this accidental readjustment (proGAV, proSA).

Most programmable valves tend to overdrainage in the vertical position of the body. However, when combined with anti-siphon devices, they can have good results and resist siphoning. The programmed settings can be changed by external magnetic fields, but there are already valves that resist this accidental readjustment (proGAV, proSA).

There are also new devices that are based on microelectromechanical systems (MEMS), such as the Chronoflow valve. It adjusts its flow resistance continuously, responding quickly to postural changes. Unfortunately, like other types of shunt valves, they still have the problem of being easily contaminated with particles that adhere to their structures.

**Radiological findings**

Considering the radiological findings of overdrainage, small ventricles are most found, possibly indicating SVS. Extra-dural collections of CSF or blood may also occur in the findings, due to the decrease in ventricular volume. Depending on the acute, subacute, or chronic blood content, the collections can be hyperdense, dense, or hypodense when seen by computed tomography (CT). There is also the possibility of finding bone changes, such as microcephaly, sclerosis of the sutures, narrowing of the foramen of the skull base, among others.

On skull and meninges MRIs, invagination of the cortex, distension of the basilar trunk or cranial nerves, and caudal displacement of the diencephalon and cerebellar tonsils (brain sagging) usually appear. The spine may show signs of engorgement of the epidural venous plexus, stenosis of the lumbar canal and spinal cord compression, which is rarer.

**Negative pressure hydrocephalus**

Negative pressure hydrocephalus (NegPH) is a rare clinical condition created iatrogenically with the development of symptomatic hydrocephalus, despite subnormal ICP. It is characterized by enlarged ventricles and symptoms consistent with increased ICP.

It was first described in 1995 by Vassilyadi et al., in two pediatric patients with hydrocephalic symptoms, negative ICP reported, and clinical improvement with modification of cystplureal shunts to increase resistance to CSF flow. The three most important factors related to NegPH are cerebral compliance, transmastic pressure, and cerebral turgor.

Fillipidis et al. suggested that CSF leaks play a central role in the development of a hydrocephalic state of negative pressure, producing a very low subarachnoid pressure. Overdrainage of the external cyst and the consequent loss of fluid from the cranial subarachnoid space (CSAS) resulted in low pressure from the CSAS. This operated as a "vacuum" for the ventricles, increasing the transmastic pressure gradient and promoting hydrocephalus with a negative ICP. For the first time, Vasilyadis et al. suggested that deviation of the lumbar thecal sac could result in a pressure difference between the ventricles and the cortical subarachnoid space, leading to an increase in ventricular volume and symptoms of high ICP, but with very low values. With forced drainage of CSF, the patient's condition improves, and the ventricles decrease in size.

The therapeutic point of view was to recover the ventricular enlargement back to normal size as far as possible from hydrocephalus with ventriculomegaly, regardless of high, low, or negative ventricular pressure. Patients with negative pressure hydrocephalus often undergo multiple shunt reviews, with no success in reversing the signs of ventriculomegaly. Patients show a declining level of consciousness and function, with reductions in areas such as appetite, energy, speech, motor function, and balance. The clinical picture is similar to ventriculomegaly associated with symptoms of elevated ICP, as they share signs and symptoms such as low level of consciousness, headaches, vomiting, and cranial neuropathies.

When the viscoelastic properties, brain compliance, and turgor are improved and the transmastic pressure between ventricles and the cortical subarachnoid space disappears, the ventricular pressure increases. In this case, it is suggested the ventriculoperitoneal shunt to be considered as soon as the ventricular pressure rises above 50 and 60 mmHg, in which a programmable pressure valve should work well. No programmable anti-siphon devices should
be selected for patients with negative hydrocephalus to prevent inadequate CSF drainage\textsuperscript{39}.

\textbf{CSF flow variation}

Changes in the pattern and speed of CSF flow can be observed from the most varied factors. In hydrocephalus, the disease itself causes a 2.7-fold increase in flow, on average, compared to a healthy individual. During rapid eye movements (REM) sleep periods, there were also changes that coincided with the involuntary movements of the eyeballs, breathing, and swallowing. Sleep disorders, such as obstructive apnea, reduce oxygen pressure and cause negative intrathoracic pressure, and can cause an increase in intracranial venous pressure, directly influencing the CSF flow\textsuperscript{61-63}.

Seizures increase intrathoracic pressure and, in parallel, ICP for a short period of time, leading to an abrupt change in liquid flow. When assessing age, older people have a greater amount of CSF, due to the decrease in brain mass and dilation of the ventricles\textsuperscript{14,64,65}.

In addition, postural variation is an important factor in the abrupt change in flow. When changing from horizontal to vertical position, the descending CSF flow is noted, towards the lumbar dural sac. Gravitational effects can also cause changes\textsuperscript{66}.

\textbf{Glymphatic system}

The glymphatic system, named in 2012 from in vivo studies using two-photon microscopy in mice, was able to influence the CSF flow from its physiological functioning. This system is analogous to the body’s lymphatic system, but it acts only on the central nervous system, both in cleaning and in the exchange of metabolites. It was found that during sleeping, the perivascular spaces expand by 60%, allowing a greater influx of CSF through the parenchyma and, consequently, altering the hydrodynamics of the CSF\textsuperscript{41,67-70}.

Flow changes can also be apparently caused by arterial pulsations, passive diffusion, and mass flow dependent on aquaporin-4 (AQP4) and aquaporin-1 (AQP1), being related to the functioning of the glymphatic system in the direction of CSF-ISF (interstitial fluid) exchange. However, there is still no clear evidence on the factors that influence the flow\textsuperscript{71-73}.

The AQP\textsubscript{s} levels might help the clinicians to support the diagnosis of a shunt malfunction in difficult cases like patients with overdrainage and slit-ventricle syndrome. A study had postulated the hypothesis that in overdrainage cases, AQP\textsubscript{s} levels should not be altered compared to controls. In the slit ventricle syndrome, they would show variations in the concentration\textsuperscript{74}.

In 2014, a computational model was described that combines hypotheses about the glymphatic system, made with the proposal of determining the osmolarity of the extracellular space, blood, and CSF in the brain to establish relationships about pathological disorders and osmotic imbalances that can cause, among some pathologies, hydrocephalus. This model still needs better validations to be proven as effective in studies\textsuperscript{75}.

Recent research has raised the hypothesis of a relationship between disorders of glymphatic clearance and neurological diseases, such as Alzheimer’s disease and idiopathic normal pressure hydrocephalus. The delay in clearance can reduce the CSF flow, which is already relatively compromised in the elderly, and increase the amount of CSF in the ventricles. However, this is a topic that needs studies to prove the hypotheses\textsuperscript{63,75,76}.

\textbf{CONCLUSION}

The third and fourth generation valves have shown promise in the prevention and treatment of overdrainage in hydrocephalic patients. However, these devices are still very expensive and, therefore, can become difficult to be accessed, especially for low-income countries population. In this way, the second-generation can be useful when used with anti-siphon devices. The Chronoflow device is modern and could represent a new generation of valves. Therefore, overdrainage remains a complication without cure and difficult to treat, but nowadays, new technologies are proving to be increasingly effective in preventing it.

\textbf{Study limitations}

This study described the valves used in the treatment and prevention of overdrainage in hydrocephalus. The lack of clinical trials related to the subject and the low number of patients in the studies may generate a limitation bias in the study.
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