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ARTÍCULO ORIGINAL

Infection Associated with Ventricular Shunt Devices: Nelaton Catheters vs. Ventriculostomy Kit. Multicenter Cross-Sectional Study in Bogotá, Colombia

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Abstract

Introduction: Infections in patients with external ventricular drains are frequent and serious complications that remain poorly characterized in the local context. The use of Nelaton tubes as ventriculostomy catheters is widespread in Bogotá, Colombia. Although unconventional, these alternatives are significantly more affordable than commercial ventriculostomy kits.

Materials and methods: A multicenter, cross-sectional descriptive study with an analytical component was conducted to determine the prevalence of infections, complications, and mortality associated with the type of ventricular shunt device used in three neurosurgical centers in Bogotá, Colombia.

Results: A total of 319 patients with ventricular shunts—using either Nelaton catheters or commercial kits— were included in the study. The results showed a higher prevalence of infection in the Nelaton catheter group than in the commercial kit group (21.9% vs. 15.3%). Moreover, mortality was higher among patients with subarachnoid hemorrhage who received Nelaton catheters.

Discussion: Although the use of Nelaton catheters is common in local neurosurgical practice due to their availability and lower cost, the findings suggest a potentially increased risk of infection and adverse outcomes. These results underscore the need for further research to rigorously evaluate the safety and clinical implications of using Nelaton catheters as substitutes for standard ventriculostomy devices.

Keywords: External ventricular drain; Infection; Ventriculostomy; Postoperative Complications

Infección asociada a dispositivos de derivación ventricular: catéteres Nelaton vs. kit de ventriculostomía. Estudio multicéntrico de corte transversal en Bogotá, Colombia

Resumen

Introducción: Las infecciones en pacientes con drenajes ventriculares externos son una complicación frecuente y grave que aún no se ha descrito con precisión en el contexto local. El uso de tubos de Nelaton como catéteres de ventriculostomía está extendido en Bogotá, Colombia. Estas alternativas, aunque poco convencionales, son significativamente más económicas que los kits comerciales de ventriculostomía.

Materiales y métodos: Se realizó un estudio descriptivo transversal multicéntrico con un componente analítico para determinar la prevalencia de infecciones, complicaciones y mortalidad asociadas con el tipo de dispositivo de derivación ventricular utilizado en tres centros neuroquirúrgicos de Bogotá, Colombia.

Resultados: Se incluyó en el estudio a un total de 319 pacientes con derivaciones ventriculares, ya sea con catéteres Nelaton o kits comerciales. Los resultados mostraron una mayor prevalencia de infección en el grupo con catéter Nelaton que en el grupo con kits comerciales (21,9 % frente a 15,3 %). Además, la mortalidad fue mayor entre los pacientes con hemorragia subaracnoidea que recibieron catéteres Nelaton.

Discusión: Si bien el uso de catéteres Nelaton es común en la práctica neuroquirúrgica local debido a su disponibilidad y menor costo, los hallazgos sugieren un posible aumento del riesgo de infección y resultados adversos. Estos resultados subrayan la necesidad de realizar más investigaciones para evaluar rigurosamente la seguridad y las implicaciones clínicas del uso de catéteres Nelaton como sustitutos de los dispositivos de ventriculostomía estándar.

Palabras clave: Drenaje ventricular externo; Infección; Ventriculostomía; Complicaciones postoperatorias.

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Recibido: 03/03/2025; Aceptado: 14/04/2026

Cómo citar este artículo: J.L. Chávez-Moreno, *et al.* Infection Associated with Ventricular Shunt Devices: Nelaton Catheters vs. Ventriculostomy Kit. Multicenter Cross-Sectional Study in Bogotá, Colombia. Infectio 2026; 30(3): 261-266

Introduction

The drainage of cerebrospinal fluid (CFS) using external ventricular drains (EVD), particularly intraventricular catheters, is one of the most common yet most complex procedures performed by neurosurgeons. EVDs, also called ventriculostomy catheters, are medical devices that allow invasive, direct, and real-time monitoring of intracranial pressure (ICP). They are generally used in emergency situations, indicated in those cases in which an acute alteration occurs in intracranial hydrodynamics, as occurs in cases of secondary hydrocephalus (communicating or non-communicating). The most common causes of such alterations are spontaneous subarachnoid hemorrhage (SAH), hemorrhagic cerebrovascular events with ventricular drainage, infectious meningitis, and space-occupying lesions with obstruction of cerebrospinal flow[1].

External ventricular devices offer many advantages, such as the possibility of monitoring the clinical course of the disease and its response to treatment; they provide the ability to regulate the flow of CFS, an ability lacking in the ventriculoperitoneal shunt types; they also allow for direct access to the ventricular space, which facilitates the administration of fibrinolytics in intraventricular hemorrhage, antibiotics in ventriculitis, and the performance of diagnostic ventriculography[2].

Complications associated with EVDs include intracranial hemorrhage, incorrect insertion, disconnection, blockage, or unintentional removal of the catheter. However, the most significant complication is infection of the external ventricular shunt device. This is the most frequent and most clinically severe complication associated with EVDs. It can lead to or be associated with ventriculitis, meningitis, cerebritis, brain abscesses, and subdural empyemas, all of which negatively impact the morbidity and mortality rates of patients. Patients with infection of the EVDs can have a more arduous and lengthy post-procedure rehabilitation process; they are unable to undergo a more permanent solution, such as a ventriculoperitoneal shunt. All of these complications prolong hospital stays and increase hospitalization costs[3].

Mortality in ventriculostomy infections is reported in monocentric retrospective studies with few patients, and to date it has not been described in the local Colombian population. Kitchen et al report mortality of 58%[4], while Sam et al[5] report it as 64% which is more commonly related to the isolation of gram-negative germs. Von Der Breile et al. report that the risk of recurrence two months after a first episode of EVD is 13%, and that after this period the recurrence rate is practically zero[6].

Given that the central nervous system is a sterile environment, the isolation of a pathogen in CSF or the ventricular catheter tip is diagnostic of infection in and of itself and thus constitutes the gold standard for EVD infection, although it lacks specificity to differentiate infection from colonization. Clinical symptoms such as fever, headache, nausea, neck stiffness, decreased level of alertness, or focal neurological deficit, among others, may be indicative of neuroinfection. However, these clinical symptoms lose their sensitivity and specificity to diagnose the disease if the patient already possess one of the following conditions such as: pre-existing neurological deficit, a neurological lesion which may have been the indication for using the EVD, previously undocumented concomitant infection, treatments to avoid secondary injuries (sedation, neuromuscular blockade), epilepsy, or electrolyte disorders [7].

The Infectious Diseases Society of America (IDSA) has published some specific recommendations regarding EVD infection: clinical suspicion of EVD infection warrants a cytochemical study of CSF along with a bacterial culture test and gram stain, serial blood cultures (despite its sensitivity being variable: 23-95%), and neuroimaging techniques that allow early detection of ventriculitis and obstruction to CSF drainage. Regarding cultures, samples taken from the surgical wound, catheter tip, CSF, and blood are proposed to minimize the possibility that the isolated microorganism corresponds to a contaminating agent instead of the causal agent[8].

Materials and methods

Study Design and Setting

This investigation was designed as a cross-sectional, multicenter descriptive study with an analytical component. It was conducted at high complexity neurosurgical centers in Bogotá, Colombia, over an eight-year period from January 1, 2015, to December 31, 2022. The three chosen neurosurgical centers in Bogotá were the National University Hospital of Colombia, Kennedy Hospital, and El Tunal Hospital. The three hospitals are third-level complex healthcare institutions managed by the state, making them public institutions.

Each institution provides high-complexity neurosurgical care and maintains a digital registry of the surgical procedures.

Participants

Eligibility Criteria

The inclusion criteria comprised patients who were between 18 and 80 years of age, underwent external ventricular drain (EVD) placement during the study period at one of the three participating centers, had the procedure performed in an operating room under aseptic conditions, and received antibiotic prophylaxis according to institutional neurosurgical protocols.

The exclusion criteria were as follows: central nervous system (CNS) infection present at the time of EVD placement; EVD placement due to complications of an existing ventricular shunt system, whether definitive (ventriculoperitoneal, ventriculoatrial, or other permanent shunts) or temporary (previous ventriculostomy); pediatric patients, given the low number of such cases at participating institutions; or patients older than 80 years, as intracranial hydrodynamic disorders are uncommon in this population.

Sample Size Determination
To ensure statistical power, the minimum required sample size was calculated based on the following assumptions: estimated total population: 3,000 patients, an expected prevalence of EVD infection of 9% (1) with a confidence level of 95%.

Using these parameters, the minimum sample size required was 121 patients using the OpenEpi program.

Data Sources
After obtaining ethical approval and institutional authorization, an exhaustive review of the surgical registries from each center was performed to identify all EVD procedures between January 2015 and December 2022. The corresponding medical records were retrieved and reviewed to extract relevant clinical and procedural information.

Variables
The data collected included:
Demographic variables: age and sex.

Clinical variables: indication for EVD placement, coexistence of subarachnoid hemorrhage (SAH), and presence of EVD-related infection. Procedural variables: surgical description, type of EVD used (Nelaton catheter or commercial EVD kit), and duration of EVD placement (days).

Outcome variables: occurrence of infection (as per the CDC definition), time to infection onset (days from placement), and in-hospital mortality.

EVD infection was defined according to the Centers for Disease Control and Prevention (CDC, Atlanta, USA) diagnostic criteria for healthcare-associated ventriculitis or meningitis [9].

Bias Control
Selection bias was minimized by including all consecutive eligible patients during the study period. Information bias was reduced through standardized data abstraction from medical records by trained neurosurgical research staff using a predefined data collection form. Observer bias was minimized by ensuring that the data collectors were blinded to the study hypothesis during extraction. Objective, clinical, and laboratory-based diagnostic criteria were used to define ventriculostomy infection, and ambiguous cases were reviewed by a second neurosurgeon to ensure inter-rater reliability.

Confounding bias was reduced by identifying potential confounding variables, including age, sex, the presence of subarachnoid hemorrhage, and the type of drainage system. While causal inference is limited by the cross-sectional design, this analytical approach reduced the likelihood that observed associations were due to confounding factors rather than true differences in infection risk. Quality control was maintained through the periodic verification of the extracted data by the principal investigator. Any discrepancies were resolved through consensus using the original medical records as a reference. Data integrity was further reinforced by using an encrypted and access-controlled database.

Statistical Analysis
Descriptive statistics were used to summarize the characteristics of the study population. Continuous variables are expressed as mean ± standard deviation (SD) or median (interquartile range), depending on the distribution. Categorical variables were presented as frequencies and percentages.

Comparative analyses were performed to assess differences in infection rate and mortality between EVD types (Nelaton vs. commercial), presence vs. absence of subarachnoid hemorrhage (SAH), and duration of EVD placement (time to infection).

A 95% confidence interval (CI) was used for all estimates. The software used for data collection was REDCap, as it is a tool that complies with the required information security protocols. The data were collected, tabulated, and analyzed exclusively by the principal investigator. The database was downloaded without any patient-identifying information.

Ethical Considerations

The study protocol was reviewed and approved by the Research Ethics Committees of all participating institutions. This study was conducted in accordance with the Declaration of Helsinki and Colombian national regulations on research involving human subjects. All data were anonymized prior to the analysis to ensure patient confidentiality.

Results
Study Population
During the study period, a total of 390 external ventricular drain (EVD) placements were performed across the three participating neurosurgical centers in Bogotá, Colombia. After applying the inclusion and exclusion criteria, 71 cases were excluded, resulting in a final sample of 319 patients included in the analysis. (Figure 1).

Demographic and clinical characteristics, shunt type distribution, prevalence of infection, subarachnoid hemorrhage (SAH), and mortality rates are summarized in Table 1.

Baseline Characteristics
The Nelaton catheter was used more frequently in male patients (62.7%), whereas in female patients, the distribution between shunt types was similar. The mean age did not differ significantly between the patients with Nelaton catheters and those with commercial EVD kits.

Prevalence of Infection
A total of 61 EVD-related infections were documented, corresponding to an overall infection prevalence of 19.2%. In the Nelaton group, infection prevalence was 21.9%, compared to 15.3% in the commercial kit group, yielding a prevalence ratio (PR) of 1.34. The prevalence of SAH at the time of EVD placement was 22.2%, being 25.5% in the commercial kit group and 19.7% in the Nelaton group.

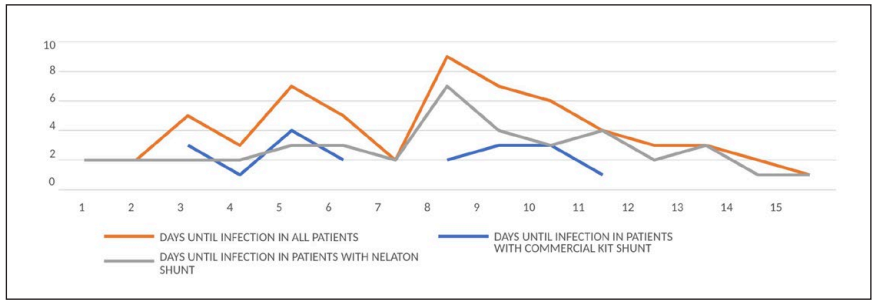

Figure 1. Frequency of infection in ventriculostomy since placement in days by type of shunt

Mortality

The overall mortality rate in this cohort was 26.3%. Mortality was 30.6% among patients treated with commercial kits and 23.1% among those treated with Nelaton catheters. Among patients with EVD infection, mortality was slightly higher among those treated with commercial kits (Table 2). In patients with coexisting SAH, both the infection rate and mortality were higher in the Nelaton group. When comparing mortality in infected patients with SAH by shunt type, higher mortality was observed in the commercial kit subgroup (Table 3).

Timing of Infection

External ventricular device infections were documented from day 1 to 15 after catheter placement. As shown in Figure 1, three infection peaks were observedon days 3, 5, and 8, with the highest peak occurring on day 8. Infections occurred 2.2 days earlier on average in the Nelaton group than in the commercial kit group. Among patients with SAH, infection occurred 1.3 days earlier than in patients without SAH (Figure 2).

Bivariate Analysis

A bivariate analysis was performed to determine the association between the following variables: sex, type of shunt, and subarachnoid hemorrhage, with theoutcome variable being ventriculostomy infection. The chi-square test was used, with a statistical significance level of $p < 0.05$. No significant association was found between the shunt type and sex (Tables 5 and 6). A statistically significant association was found between SAH and EVD infection (Tables 4 and 7).

Discussion

This multicenter analysis provides insights into the frequency and outcomes of EVD-related infections in three neurosurgical centers in Bogotá, Colombia. The overall infection rate of 19.2% was markedly higher than the <5% rate reported in the literature (10). This elevated rate has remained consistent in local institutions and aligns with the findings by Chaves et al. (2017)[11].

Infection was 6.6% more prevalent among patients with Nelaton catheters, corresponding to a prevalence ratio of 1.34. We hypothesized that this finding could be explained by the difference in system design: commercial kits employ a closed, sterile drainage system, whereas Nelaton-based systems are not fully closed, increasing the risk of exposure.

Subarachnoid Hemorrhage as a Risk Factor. Approximately 22.2% of the patients presented with SAH at the time of EVD placement. Infection was more than twice as common in SAH patients with Nelaton tubes compared to those with commercial kits (58.3% vs. 25.6%) respectively. This finding is consistent with prior evidence identifying SAH as an independent risk factor for ventriculostomy-related infection (12). *Mortality and Clinical Impact.* The overall mortality rate in this series was 26.3%. Although the infection rates were higher in the Nelaton group, the mortality rate was slightly higher in the commercial kit group (30.6%). Among all infected patients, mortality reached 55.7%, reflecting the severe clinical impact of these infections and mirroring the rates reported in the international literature (13). Patients with Nelaton catheters and concurrent SAH had the highest infection burden but not a proportionally higher mortality rate, possibly due to the differing disease severity at baseline.

Temporal Patterns of Infection. The temporal distribution of infections revealed peaks on postoperative days 3, 5, and 8, with the principal peak on day 8, which contrasts with international reports citing day 5 as the most frequent (14). Infections developed earlier in Nelaton systems and in SAH cases, suggesting that catheter material and early postoperative manipulation could influence infection timing. This

Table 1. Demographic characteristics

Shunt type	sex		average age	infection	SAH	mortality
	male	female				
Commercial kit (n=132)	78 (39%)	59 (49.6%)	56 ± 17.8	21 (15.3%)	35 (25.5%)	42 (30.6%)
Nelaton (n=187)	122 (61%)	60 (50.4%)	56.4 ± 15.6	40 (21.9%)	36 (19.7%)	42 (23.1%)
Total (n=319)	200 (62.7%)	119 (37.3%)	56.3±16.7	61 (19.2%)	71 (22.2%)	84 (26.3%)

SAH: Subarachnoid hemorrhage

observation, which has not been previously documented, warrants further investigation into device-handling practices and material-related risks.

Statistical and Clinical Interpretation. No significant statistical association was found between sex or shunt type and infection occurrence. However, SAH showed a statistically significant correlation, suggesting a possible causal relationship that should be further explored in prospective studies. Despite the lack of statistical correlation, the clinical trend remains notable: 65.6% of all infections and 64.7% of infection-related deaths occurred in patients treated with Nelaton catheters.

Clinical and Public Health Implications. The use of Nelaton catheters as a low-cost alternative to commercial EVD kits remains common in Bogotá and throughout Latin America. While effective for temporary cerebrospinal fluid diversion, these devices lack sterile integrity and may contribute to higher infection rates. Given that EVD infection often necessitates prolonged antibiotic therapy, delayed definitive shunt placement, and extended hospitalization, the economic and clinical burdens are substantial. These infections also increase the risk of recurrent ventriculitis and long-term morbidity.

Limitations. The cross-sectional design limits causal inference regarding the shunt type and infection. Additionally, data were obtained retrospectively from medical records, which may introduce information bias. The results are not generalizable beyond the included institutions, as resource availability and infection control practices vary across settings.

Future Directions. Based on these findings, centers should prioritize the use of approved commercial EVD kits and implement them with full regulatory and safety rigor, including staff training in sterile techniques, robust device traceability, and standardized infection surveillance. In parallel, institutions should evaluate the development of locally engineered devicespursued with the same regulatory rigor, quality assurance, and clinical validation, aiming to achieve equivalent safety and performance at a more sustainable cost.

External ventricular drain (EVD) infections remain a frequent and severe complication in neurosurgical practice, associated with high morbidity and mortality. The findings of this multicenter study indicate that the prevalence of EVD infection is higher among patients treated with Nelaton catheters compared to those who received commercial drainage kits, particularly when subarachnoid hemorrhage is present.

In developing countries such as Colombia, resource limitations often lead to the use of non-standard or non-certified medical devices. However, this reality must not translate into an increased risk for patients. Studies such as this play a crucial role in documenting the clinical implications of using non-validated devices, highlighting the importance of safety and quality in neurosurgical practice.

Promoting the use of validated and commercially approved drainage systems represents both an ethical and practical strategy to reduce avoidable complications and safeguard patient outcomes. Future research, ideally through randomized controlled or prospective cohort studies, is required to establish the causal relationship between shunt type and infection risk, as well as to assess the cost-effectiveness of different drainage systems in low-resource settings, while advancing the development of domestically engineered devices held to the same rigor—adhering to regulatory approval pathways, good manufacturing practices, biocompatibility and sterility testing, and formal clinical validation.

In conclusion, while local constraints may necessitate pragmatic decisions, ensuring patient safety through adherence to quality standards must remain a non-negotiable priority

Table 2. Mortality in infected individuals according to shunt type

Shunt type + infection	Mortality
Commercial kit (n=21)	12 (57.4%)
Nelaton (n=40)	22 (55%)
Total (n=61)	34 (55.7%)

Table 3. Prevalence of infection and mortality according to shunt type with SAH

Shunt type	Infection	Mortality
Commercial kit (n=35)	10 (25.6%)	16 (45.7%)
Nelaton (n=36)	21 (58.3%)	20 (55.6%)
Total (n=71)	31 (43.6%)	36 (50.7%)

SAH: Subarachnoid hemorrhage

Table 4. Mortality according to shunt type in individuals with infection and SAH

Shunt type + SAH + infection	Mortality
Commercial kit (n=9)	7 (77.8%)
Nelaton (n=11)	7 (63.4%)
Total (n=20)	14 (70%)

SAH: Subarachnoid hemorrhage

Table 5. Bivariate analysis of infection per shunt type

Infection	Shunt type		Total
	Commercial kit	Nelaton	
No	116	142	258
Yes	21	40	61
Total	137	182	319

Table 6. Bivariate analysis of infection per sex

Infection	Shunt type		Total
	Female	Male	
No	90	168	258
Yes	29	32	61
Total	119	200	319

Table 7. Bivariate analysis of infection in relation to the presence subarachnoid hemorrhage

Infection	Subarachnoid hemorrhage		Total
	No	Yes	
No	213	40	258
Yes	30	31	61
Total	248	71	319

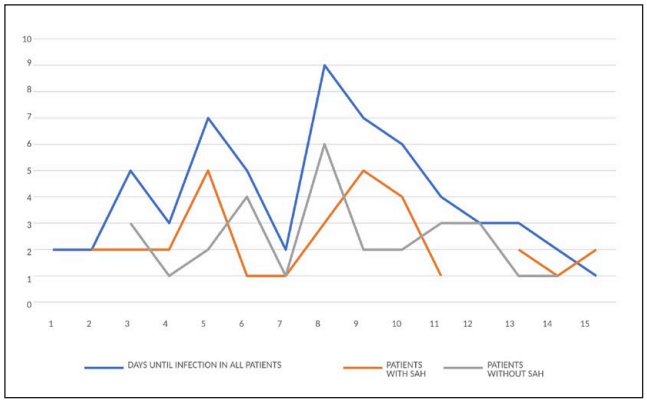

Figure 2. Frequency of infection in ventriculostomy with subarachnoid hemorrhage since placement in days

in neurosurgery. Strengthening evidence-based practice and advocating equitable access to certified medical technologies are essential steps toward improving neurosurgical care in developing contexts.

Ethical considerations

Protection of persons. No experiments were performed in animals nor humans for the elaboration of this project.

Protection of vulnerable populations. Vulnerable patients such as children, people with reduced physical/intellectual abilities, economically vulnerable, or institutionalized people were not included in this study

Confidentiality. The authors declare that the text does not contain data that allows patient identification. This study was conducted considering Resolution 8439 of 1993, which regulates ethical aspects of research in Colombia and allows the classification of it as having no risk for the participants.

Privacy. Patient identifying data were not disclosed in this study and were kept anonymous throughout the data analysis.

Financing. The authors declare that they have not received any type of funding.

Conflict of interests. The authors have no conflict of interest to declare.

Acknowledgments. The authors thank the participating neurosurgical centers and their clinical, administrative, and records-management staff for facilitating access to institutional surgical registries and medical records. The authors also acknowledge the support of the neurosurgical teams involved in patient care during the study period. No specific financial support was received for this work.

Statement on the use of artificial intelligence. The authors declare that no generative artificial intelligence tools, including ChatGPT or other AI-assisted technologies, were used in the writing, editing, data collection, data analysis, interpretation of results, or preparation of this manuscript. All sections of the manuscript were prepared, reviewed, and approved by the authors, who assume full responsibility for the accuracy, integrity, and final content of the submitted work.

Authors´ contribution. Conceptualization: J.M., S.Q., D.G. Ideas: J.M., S.Q., D.G Supervision: D.G. Visualization S.J., L.R Writing – original draft – J.M. Writing – review & editing – J.M., S.Q., D.G., B.G., M.R., A.V., S.J., L.R. All authors contributed to read and approved the version of the submitted manuscript.

References

1. Ramanan,M.,Lipman,J.,Shorr,A.,Shankar,A.,&Burrell,A.(2015).A meta-analysis of ventriculostomy-associated cerebrospinal fluid infections. BMC Infectious Diseases, 15(1), 3–12. https://doi.org/10.1186/s12879-014-0712-z
2. Connolly,E.S.,Jr.,Rabinstein,A.A.,Carhuapoma,J.R.,Derdeyn,C.P., Dion, J., Higashida, R. T., Hoh, B. L., Kirkness, C. J., Naidech, A. M., Ogilvy, C. S., Patel, A. B., Thompson, B. G., Vespa, P., Zuccarello, M., & Neurocritical Care Society. (2016). The insertion and management of external ventricular drains: An evidence-based consensus statement. *Neurocritical Care, 24*(1), 61–81. https://doi.org/10.1007/s12028-015-0224-8 3
3 Lozier,A.P.,Sciacca,R.R.,Romagnoli,M.F.,&Connolly,E.S.(2002). Ventriculostomy-related infections: A critical review of the literature. *Neurosurgery, 51*(1), 170–181. https://doi.org/10.1097/00006123-200207000-00023
4. Kitchen WJ, Singh N, Hulme S, Galea J, Patel HC, King AT. External ventricular drain infection: improved technique can reduce infection rates. Br J Neurosurg. 2011;25(5):632–5. DOI: 10.3109/02688697.2011.578770
5. Sam J, Lim C, Sharda P, Wahab N. The organisms and factors affecting outcomes of external ventricular drainage catheter-related ventriculitis: A Penang experience. Asian J Neurosurg. 2018;13(2):250–7. DOI: 10.4103/ajns.AJNS_150_16
6. VonderBrelieC,SimonA,GrönerA,MolitorE,SimonM.Evaluationofan institutional guideline for the treatment of cerebrospinal fluid shunt-associated infections. Acta Neurochir (Wien). 2012;154(9):1691–1697. DOI: 10.1007/s00701-012-1329-x
7. HernándezOrtizOH,GarcíaGarcíaHI,MuñozRamírezF,CardonaFlórez JS, Gil Valencia BA, Medina Mantilla SE, Moreno Ochoa MJ, Sará Ochoa JE, Jaimes F. Development of a prediction rule for diagnosing postoperative meningitis: a cross-sectional study. J Neurosurg. 2018 Jan;128(1):262–271. doi: 10.3171/2016.10.JNS16379.
8. Tunkel AR, Hasbun R, Bhimraj A, et al. 2017 Infectious Diseases Society of America's Clinical Practice Guidelines for Healthcare-Associated Ventriculitis and Meningitis. Clin Infect Dis. 2017 Nov 29;64(6):e34–e65. doi: 10.1093/cid/ciw861
9. CentersforDiseaseControlandPrevention.(2023).NationalHealthcare Safety Network (NHSN) patient safety component manual: Ventriculitis or meningitis (VC). U.S. Department of Health and Human Services. https://www.cdc.gov/nhsn/pdfs/pscmanual/pcsmanual_current.pdf
10. Hoefnagel, D. P., Nijeboer, M. N., Peerdeman, S. M., & Verweij, B. H. (2023). Ventriculostomy-related infection rate in an intensive care population. BMC Neurology, 23, Article 36. https://doi.org/10.1186/s12883-023-03080-2
11. Chávez Moreno, J. (2023). *Infección asociada a dispositivos de derivación ventricular en Bogotá: un estudio multicéntrico* (Tesis de pregrado, Universidad Nacional de Colombia)
12. Zhou, J., Zhong, Y., Li, X., Li, H., Wang, J., Yang, S., & Chen, G. (2023). Risk factors for external ventricular drainage–related infection: A systematic review and meta-analysis. Neurology: Clinical Practice, 13(4), e200156. https://doi.org/10.1212/CPJ.0000000000200156
13. Corona-Nakamura, A. L., Arias-Merino, M. J., Ávila-Esparza, E. I., & others. (2024). *Ventriculitis due to multidrug-resistant gram-negative bacilli associated with external ventricular drain: Evolution, treatment, and outcomes. Frontiers in Neurology, 15*, 1384206. https://doi.org/10.3389/fneur.2024.1384206
14. Walek, S., Crowley, R., Cheema, S., & Simões, R. (2014). *External ventricular drain infections: Risk factors and outcome. Interdisciplinary Perspectives on Infectious Diseases, 2014*, 708531. https://doi.org/10.1155/2014/708531