Chapter 9

External Ventricular Drainage (EVD) Complications and Management, From Recent Literature

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Abstract

External ventricular drainage (EVD) remains indispensable for intracranial pressure (ICP) monitoring and cerebrospinal fluid (CSF) diversion in neurocritical care. Despite advances in catheter design and infection prevention strategies, complication rates remain substantial. This chapter adopts a comprehensive temporal framework—pre-operative risk stratification, intra-operative technical precision, and post-operative surveillance—to structure the discussion of complications. Utilizing contemporary evidence, including recent systematic reviews from 2024 and 2025, we emphasize that protocol-driven, team-based care offers the most reliable path to reducing EVD-related morbidity.

1. INTRODUCTION

External ventricular drains (EVDs) are among the most frequently performed neurosurgical procedures worldwide. They provide essential continuous CSF diversion and allow for direct, gold-standard intracranial pressure (ICP) monitoring $[2, 3]$. The procedure is indicated for a wide spectrum of neurological emergencies, including aneurysmal subarachnoid hemorrhage (SAH), severe intraventricular hemorrhage (IVH), traumatic brain injury (TBI), and acute hydrocephalus related to various etiologies $[2, 3, 5]$.

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While EVDs are life-saving tools, they are invasive devices associated with a significant burden of complications. These complications are generally categorized into three main domains: hemorrhagic events (tract hemorrhage, vascular injury), mechanical failures (malposition, obstruction, migration), and infectious complications (ventriculitis/meningitis) $[1, 3, 7]$. The impact of these complications is profound, often leading to prolonged intensive care unit (ICU) stays, the need for additional surgical interventions (such as hematoma evacuation or shunt placement), and increased overall mortality $[1, 4]$.

Recent literature underscores that many of these complications are modifiable. For instance, catheter malposition and hemorrhage are often functions of technical execution and patient selection $[6, 9, 8]$, while infection rates are closely tied to maintenance protocols and catheter dwell time $[1, 12]$. By organizing EVD management into a phased approach, clinicians can systematically address risks at the pre-operative, intra-operative, and post-operative stages $[2, 3]$.

2. PRE-OPERATIVE PHASE: RISK STRATIFICATION AND OPTIMIZATION

2.1. Hemorrhagic Risk Assessment

Hemorrhage associated with EVD placement remains one of the most feared acute complications. While minor tract hemorrhages are relatively common and often asymptomatic, clinically significant hematomas can be devastating $[4, 9, 10]$.

- **Coagulopathy and Platelet Thresholds:** Pre-existing coagulopathy is the most significant modifiable risk factor. The Neurocritical Care Society (NCS) consensus statement historically recommended maintaining an international normalized ratio (INR) ≤ 1.4 and a platelet count $>100,000/\text{mm}^3$ for elective procedures $[3]$. However, more recent data suggest that these thresholds require nuance. A 2024 study by Windermere et al. identified that a platelet count $<120\times 10^3/\mu \text{L}$ is an independent predictor of tract hemorrhage $[4]$. This suggests that the traditional cutoff of $100,000/\text{mm}^3$ might be insufficient for preventing all hemorrhagic events, particularly in high-risk patients.
- **Antiplatelet Therapy:** The use of antiplatelet agents poses a specific challenge. Recent analyses indicate that antiplatelet exposure is a critical variable in the development of hemorrhagic complications

$[4]$. Therefore, reversal strategies or the timing of discontinuation must be carefully planned in the pre-operative phase.

- **Reversal Strategies:** For patients with coagulopathy, rapid reversal is essential. Protocols typically involve the use of prothrombin complex concentrates (PCC) or fresh frozen plasma (FFP) to normalize INR, and platelet transfusions to reach safe thresholds prior to catheter insertion $[2, 3]$.

2.2. Infection Prevention: The Pre-operative Component

Infection is the dominant late complication of EVDs. Understanding the pathophysiology is key to prevention. Mounier et al. demonstrated that bacterial colonization typically follows a "skin-to-brain" route, migrating extraluminally from the insertion site along the catheter tract $[12]$. This finding highlights that the battle against infection begins before the incision is made.

- **Prophylactic Antibiotics:** Consensus guidelines strongly support the administration of a single dose of prophylactic antibiotics prior to skin incision $[3]$. This practice is standard of care and is aimed at reducing the skin flora load at the time of insertion.
- **Skin Preparation:** Given the colonization pathway, meticulous skin antisepsis is non-negotiable. Chlorhexidine-based solutions are generally preferred, and strict adherence to drying times is crucial to ensure efficacy $[1, 3]$.

2.3. Anatomical Considerations and Planning

Anatomical complexity, such as "small ventricle" syndrome or significant midline shift, drastically increases the difficulty of freehand placement $[8]$.

- **Imaging Review:** Pre-operative imaging must be scrutinized to identify the trajectory. In patients with shifted ventricles, standard landmarks (Kocher's point) may result in the catheter traversing eloquent cortex or missing the ventricle entirely $[8, 9]$.
- **Technique Selection:** The choice of insertion technique matters. Staartjes et al. (2020) compared twist-drill craniostomy with standard burr-hole trephination, noting differences in accuracy and complication profiles $[6]$. For patients with challenging anatomy, the use of image guidance or neuronavigation should be considered to minimize the number of passes required, as multiple passes are a known risk factor for hemorrhage $[9, 10]$.

3. INTRA-OPERATIVE COMPLICATIONS: TECHNICAL PRECISION

3.1. Minimizing Hemorrhagic Events

Intra-operative technique is directly correlated with bleeding risk.

- **Number of Passes:** There is a linear relationship between the number of ventricular passes and the risk of hemorrhage. Miller et al. (2017) and Windermere et al. (2024) both emphasize that repeated attempts disrupt the brain parenchyma and increase the likelihood of striking a vessel $[4, 9]$. A widely accepted practice is to limit attempts (e.g., to three passes) before abandoning the procedure or seeking image guidance $[8]$.
- **Vascular Injury:** Although rare, iatrogenic vascular injuries (such as damage to the thalamostriate vein, internal cerebral vein, or anterior choroidal artery) carry high mortality $[10]$. Kosty et al. reviewed such cases, noting that these injuries often result from trajectories that are too deep or too medial $[10]$. Surgeons must strictly adhere to depth limits (typically 5-7 cm from the inner table) to avoid entering the basal cisterns or damaging deep vascular structures $[8]$.

3.2. Catheter Malposition

Accurate placement is defined as the catheter tip residing in the ipsilateral frontal horn or at the foramen of Monro $[8, 9]$.

- **Bedside Accuracy:** Kakarla et al. reported that bedside freehand placement has a variable accuracy rate, with a significant portion of catheters ending up in suboptimal locations (e.g., basal ganglia, corpus callosum, or contralateral ventricle) $[8]$. Malposition not only leads to poor drainage but can also cause direct parenchymal injury and hemorrhage $[6, 8]$.
- **Mitigation:** The use of surface landmarks must be precise. In cases of significant anatomical distortion, relying solely on landmarks is prone to error, and alternative guidance methods are recommended $[6, 8]$.

3.3. The Role of Tunneling: Short vs. Long

Tunneling technique is a critical, yet often overlooked, step in infection prevention.

- **Pathophysiology of Tunneling:** Since bacteria migrate from the skin along the catheter $[12]$, a longer subcutaneous tunnel theoretically increases the distance and time required for pathogens to reach the CSF.
- **Evidence for Long-Tunneling:** A newly published systematic review and meta-analysis by Fariña Nuñez et al. (2025) provides compelling evidence on this topic. The study compared standard tunneling with Long-Tunneled External Ventricular Drainage (LTEVD). The findings suggest that LTEVD is a robust structural intervention that can significantly reduce infection rates in both pediatric and adult populations $[13]$. This supports the practice of tunneling the catheter at least 5-10 cm away from the burr hole site, rather than a short exit, to create a more effective barrier against bacterial ingress.

4. POST-OPERATIVE COMPLICATIONS: SURVEILLANCE AND MAINTENANCE

4.1. The "Bundle Approach" to Maintenance

Post-operative care is best managed through "bundles"—a structured set of evidence-based practices performed collectively.

- **Bundle Efficacy:** Hong et al. (2021) demonstrated that the implementation of a strict EVD care bundle led to a significant reduction in infection rates $[1]$.
- **Bundle Components:** An effective bundle typically includes:
  - **Standardized Dressing Changes:** Using sterile technique for all dressing manipulations $[1]$.
  - **Closed Systems:** Maintaining a closed drainage system and minimizing disconnections $[1, 3]$.
  - **Sampling Protocols:** Limiting CSF sampling to clinical indications (e.g., fever, meningismus) rather than routine daily sampling, which increases the risk of introducing contamination $[1, 3]$.
  - **Daily Review:** Assessing the daily necessity of the EVD and removing it as soon as it is no longer indicated $[1, 3]$.

4.2. Diagnosis and Management of Ventriculitis

Despite best practices, infections occur.

- **Diagnosis:** EVD-associated ventriculitis is diagnosed based on CSF parameters (pleocytosis, low glucose, high protein) and positive cultures $[3]$. However, distinguishing colonization from true infection can be challenging.
- **Management:** The mainstay of treatment is the initiation of appropriate systemic antibiotics. In many cases, the infected hardware must be removed or exchanged to clear the infection, as biofilms on the catheter surface can render antibiotic therapy ineffective $[3]$.

4.3. Obstruction and Hemorrhage Management

- **Catheter Obstruction:** Obstruction by blood clot or debris is common, particularly in IVH patients. Management involves checking the system integrity and leveling $[2]$. If obstruction persists, gentle irrigation with small volumes of preservative-free saline is the standard first-line intervention $[3]$.
- **Intraventricular Hemorrhage (IVH) Management:** In cases of severe IVH, maintaining catheter patency is crucial for clot clearance. Hinson et al. (2010) discussed the management of IVH, noting that intraventricular fibrinolysis (e.g., tPA) has been explored to accelerate clot resolution and maintain EVD patency, although this requires careful patient selection to avoid bleeding complications $[11]$.

4.4. Weaning and Removal Strategies

Weaning the patient from the EVD is a critical decision point.

- **Protocols:** There are two main methods: gradual elevation of the drain height (to challenge CSF absorption) or a "clamp and scan" trial $[3]$. Both methods aim to assess the patient's ability to manage CSF dynamics independently.
- **EVD vs. Lumbar Drainage:** A 2025 meta-analysis by Musmar et al. compared outcomes between EVD and lumbar drainage in SAH patients. While EVD remains the standard for acute hydrocephalus with high ICP, the study suggests that the method of CSF diversion impacts outcomes, and in some contexts (like vasospasm prevention or clearance of blood), different strategies might be considered $[5]$.

- **Removal Risks:** Even the removal of the EVD carries risks. Miller et al. (2017) highlighted that hemorrhage can occur upon removal, particularly in patients who have developed new coagulopathies or have had the catheter in place for an extended period $[9]$. Therefore, coagulation parameters should be re-checked prior to removal.

5. CONCLUSION

The management of External Ventricular Drains requires a disciplined, phase-based approach to minimize complications.

- **Pre-operatively**, identifying high-risk patients (platelets $<120\ text{k}$ $[4]$) and optimizing coagulation is paramount.
- **Intra-operatively**, technical precision—limiting passes $[9]$, utilizing image guidance for complex anatomy $[6]$, and employing long-tunneling techniques $[13]$—can reduce both hemorrhagic and infectious risks.
- **Post-operatively**, strict adherence to care bundles $[1]$ and rational weaning protocols $[3, 5]$ ensures the best possible outcomes.

Current evidence, from foundational consensus statements to the most recent 2025 meta-analyses, consistently reinforces that standardized, protocol-driven care is superior to ad-hoc management in preventing EVD-related morbidity.

References

1. Hong B, Apedjinou A, Heissler HE, et al. Effect of a bundle approach on external ventricular drain-related infection. *Acta Neurochir*. 2021;163(5):1135–1142. doi:10.1007/s00701-020-04698-8.
2. Bertuccio B, et al. External ventricular drainage: a practical guide for neuro-anesthesiologists. *Clinics and Practice*. 2023;13(1):20. doi:10.3390/clinpract13010020.
3. Fried HI, Nathan BR, Rowe AS, et al. The insertion and management of external ventricular drains: an evidence-based consensus statement: a statement for healthcare professionals from the Neurocritical Care Society. *Neurocrit Care*. 2016;24(1):61–81. doi:10.1007/s12028-015-0224-8.
4. Windermere SA, Mehkri Y, Yan SC, et al. Risk factors and outcomes associated with external ventricular drain related hemorrhage. *Clin Neurol Neurosurg*. 2024;243:108386. doi:10.1016/j.clineuro.2024.108386.
5. Musmar B, Abdalrazeq H, Roy JM, Salim HA, Pontarelli MK, Adeeb N, et al. Outcomes of external ventricular drainage and lumbar drainage in aneurysmal subarachnoid hemorrhage: A systematic review and meta-analysis. *Int J Stroke*. 2025 Jul 15 [Epub ahead of print]. doi: 10.1177/17474930251361211.
6. Staartjes VE, Serra C, Regli L, Vasella F. Accuracy and complication rates of external ventricular drain placement with twist drill and bolt system versus standard trephine and tunnelation: a retrospective population-based study. *Acta Neurochir (Wien)*. 2020;162(7):1605–1615. doi:10.1007/s00701-020-04247-3.
7. Kaya A, Türk CC, Gürkanlar D, et al. External ventriküler dren komplikasyonları: 5 yıllık deneyim. *Turk Neurosurg*. 2022;32(1):103–111. doi:10.5137/1019-5149.JTN.32663-21.0.
8. Kakarla UK, Kim LJ, Chang SW, Theodore N, Spetzler RF. Safety and accuracy of bedside external ventricular drain placement. *Neurosurgery*. 2008;63(1 Suppl):ONS162–ONS166. doi:10.1227/01.NEU.0000335031.23521.D0.
9. Miller C, Tummala RP. Risk factors for hemorrhage associated with external ventricular drain placement and removal. *J Neurosurg*. 2017;126(1):289–297. doi:10.3171/2015.12.JNS152341.
10. Kosty J, Pukenas B, Smith M, Storm PB, Zager E, Stiefel M, et al. Iatrogenic vascular complications associated with external ventricular drain placement: a report of 8 cases and review of the literature. *Neurosurgery*. 2013 Jan;72(1):208-13. doi: 10.1227/NEU.0b013e318279e783.
11. Hinson HE, Hanley DF, Ziai WC. Management of intraventricular hemorrhage. *Current Neurology and Neuroscience Reports*. 2010;10(2):73–82. doi:10.1007/s11910-010-0086-6.

12. Mounier R, Lobo D, Cook F, et al. From the skin to the brain: pathophysiology of colonization and infection of external ventricular drain, a prospective observational study. *PLoS One*. 2015;10(11):e0142320. doi:10.1371/journal.pone.0142320.
13. Fariña Nuñez MT, Percuoco V, Höbner LM, et al. Long-tunneled external ventricular drainage (LTEVD) for the prevention and treatment of infections in pediatric and adult hydrocephalus: a systematic review and meta-analysis. *Acta Neurochir (Wien)*. 2025;167:271. doi:10.1007/s00701-025-06677-3.