Chapter 9

Ventriculoperitoneal Shunt Surgery: Complications and Management, From Recent Literature

Ozan Aydoğdu[1]

Abstract

Ventriculoperitoneal (VP) shunting remains the most frequently performed neurosurgical procedure for the long-term management of hydrocephalus, yet complication and revision rates remain high despite advances in valve technology and peri-operative care. Contemporary adult and mixed-age series report overall shunt revision rates of approximately 20–40% within the first 1–2 years after implantation and even higher cumulative failure rates over longer follow-up . Shunt infection and mechanical failure are consistently identified as the leading causes of morbidity and healthcare utilization .

This chapter provides an evidence-based, temporally structured overview of VP shunt complications based on literature predominantly from 2020–2025, complemented by key earlier studies where necessary. Complications are discussed along the pre-operative, intra-operative, and post-operative phases, and are further organized by anatomical compartment (cranial, hardware-related, and abdominal). We summarize current data on risk factors, incidence, clinical presentation, diagnostic strategies, and management algorithms for shunt infection, hemorrhagic and mechanical complications, over- and under-drainage, and abdominal events such as pseudocyst formation and visceral perforation. Particular emphasis is placed on standardized preventive strategies, including the use of antibiotic-impregnated catheters, strict insertion checklists, minimally invasive distal catheter techniques, and the concept of a "Shunt Bundle" as a quality-improvement tool .

1 Corresponding Author: MD Specialist Neurosurgeon, Muğla Training and Research Hospital Department of Neurosurgery, E-mail: md.o.aydogdu@gmail.com – ORCID: 0000-0002-5998-2673

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1. INTRODUCTION

Ventriculoperitoneal (VP) shunting is the standard of care for the treatment of hydrocephalus across the age spectrum and etiologies including congenital malformations, post-hemorrhagic hydrocephalus, normal pressure hydrocephalus (NPH), tumors, trauma, and infection. Despite decades of technical refinements, shunt systems remain biologically imperfect devices, with failure and complication rates substantially higher than for most other neurosurgical implants [1–3,8,9]. Large single- and multicenter series confirm that a significant proportion of shunts require at least one revision over their lifetime, most commonly within the first 2 years after insertion [1–3]. Early failures are dominated by infection and proximal obstruction, whereas late failures are more often related to distal malfunction, valve wear, or abdominal complications [1–3,10–13].

In parallel, the hydrocephalus community has shifted from exclusively technology-driven solutions to process- and quality-driven approaches, such as standardized insertion bundles, peri-operative antibiotic protocols, and structured follow-up pathways [3–5,7,9]. Understanding the full spectrum of complications—when they tend to occur, how they present, and how they can be prevented or managed—is essential for optimizing outcomes. This chapter adopts both a temporal (pre-operative, intra-operative, early and late post-operative) and an anatomical (cranial, hardware-related, abdominal) framework to organize contemporary evidence on VP shunt complications.

2. PRE-OPERATIVE PHASE: RISK STRATIFICATION AND OPTIMIZATION

2.1. Patient-Specific Risk Factors

Age and etiology substantially influence both infection and mechanical failure profiles. Large pediatric hydrocephalus cohorts have demonstrated that infants—particularly those younger than 6–12 months—and those with post-hemorrhagic or post-infectious hydrocephalus have higher early infection and obstruction rates compared with older children, likely reflecting immature immune function, fragile skin, and small ventricular size [8,9]. In adults, patients with idiopathic or normal pressure hydrocephalus tend to have relatively lower infection rates but remain vulnerable to over-drainage and subdural hematoma, especially when aggressive valve settings are used [1,2].

Comorbidities such as diabetes mellitus, obesity, chronic renal or hepatic disease, immunosuppression, and previous abdominal surgery increase the

risk of wound complications, infection, and abdominal events [1,3,10–13]. Prior shunt infection or multiple previous revisions are consistent predictors of subsequent infection and mechanical failure, underlining the importance of meticulous technique and strict adherence to preventive protocols in high-risk patients [4,7–9].

2.2. Pre-Operative Optimization and Antimicrobial Prophylaxis

Modern protocols emphasize the correction of reversible risk factors and standardized antimicrobial strategies. Current practice builds upon infectious diseases guidelines and shunt-specific systematic reviews, which support the administration of a first-generation cephalosporin within 60 minutes of incision, with vancomycin reserved for patients colonized or infected with methicillin-resistant *Staphylococcus aureus* (MRSA) or those with severe $\ beta$-lactam allergy [6,7,9].

Several observational and controlled studies demonstrate that antibiotic-impregnated shunt catheters, in conjunction with systemic prophylaxis, significantly reduce shunt infection rates compared with standard silicone catheters, with meta-analyses reporting an approximately 50% relative reduction in infection [2,3]. In children and other high-risk populations, these benefits appear particularly pronounced and have been incorporated into guideline-level recommendations [2,3,5,9].

Coagulation should be optimized pre-operatively, particularly in adults and elderly patients. Thrombocytopenia and uncontrolled anticoagulation are associated with an increased risk of tract hemorrhage and subdural collections. When feasible, antiplatelet agents are held for an appropriate interval, and anticoagulation is bridged in accordance with cardiology and hematology recommendations. Proceeding to elective shunt placement in the setting of active systemic infection, untreated bacteremia, or uncontrolled coagulopathy is considered a preventable risk factor for serious downstream complications [6,7,9].

2.3. Definition of Pre-Operative Complications

Pre-operative complications in the context of VP shunt surgery are typically indirect and arise when modifiable risk factors are not recognized or corrected. Examples include proceeding to emergent shunting in the presence of uncontrolled systemic infection, inadequate antimicrobial prophylaxis in a colonized patient, or failure to review prior abdominal operations that might necessitate a laparoscopic or alternative distal site strategy [4,7,10–12]. Such lapses increase the likelihood of downstream

infectious, hemorrhagic, or mechanical complications and are increasingly viewed as quality-of-care issues rather than unavoidable events.

3. INTRA-OPERATIVE COMPLICATIONS

3.1. Cranial Complications: Malposition and Hemorrhage

Proximal catheter malposition is among the most frequent technical complications of VP shunt surgery. Freehand placement using surface landmarks can result in suboptimal positioning in a substantial proportion of cases, particularly in small or slit ventricles or in patients with distorted anatomy [1,8]. Neuronavigation and intra-operative ultrasound improve the accuracy of catheter placement and may reduce early obstruction and hemorrhagic events in high-risk patients, although universal adoption is limited by cost and availability [1,8].

Hemorrhagic complications include small tract hemorrhages, intraventricular hemorrhage, and less commonly clinically significant intraparenchymal bleeds. Most tract hemorrhages are radiographic findings without clinical consequence, but larger hemorrhages can lead to neurological worsening and may require surgical evacuation [1,8]. Risk factors include multiple insertion attempts, coagulopathy, and hypertensive surges. Limiting the number of passes, using image guidance in challenging cases, and optimizing blood pressure and coagulation are key preventive strategies.

3.2. Abdominal Access and Hardware-Related Issues

Traditional open mini-laparotomy for distal catheter placement has increasingly been supplanted in many centers by laparoscopic techniques, particularly in patients with prior abdominal surgery, obesity, or suspected adhesions [9–11]. Laparoscopy enables direct visualization of catheter position, reduces the risk of visceral or vascular perforation, and facilitates the management of complex distal revisions and abdominal pseudocysts [9–11]. Bowel perforation remains a rare but potentially life-threatening complication, typically presenting with peritonitis, extrusion of the catheter through natural orifices, or unexplained shunt infection [10–13].

Intra-operative hardware complications include catheter kinking, fracture, or disconnection at valve–catheter interfaces. These events can often be prevented by careful handling, appropriate trimming of catheter length, and secure fixation of connectors. Before wound closure, the entire system should be inspected and gently irrigated to confirm patency.

4. EARLY POST-OPERATIVE COMPLICATIONS (≤ 30 DAYS)

4.1. Shunt Infection

Shunt infection typically presents within the first few months after implantation and remains one of the most serious early complications. The majority of infections are caused by skin flora—coagulase-negative staphylococci and *Staphylococcus aureus*—although Gram-negative bacilli and other organisms are increasingly recognized [6–9]. Clinical manifestations range from low-grade fever, wound erythema, and subtle shunt malfunction to frank meningitis, ventriculitis, or abdominal sepsis.

Diagnosis relies on CSF analysis obtained via shunt tap or external ventricular drainage, blood cultures, and imaging when indicated [6,7]. Current guidelines and systematic reviews converge on a staged management strategy: complete removal of the infected shunt system, temporary external CSF drainage, and targeted intravenous antibiotic therapy based on culture results [6,7]. Partial shunt revision or *in situ* irrigation is associated with unacceptably high recurrence rates and should be avoided [7,9]. Re-implantation is deferred until CSF cultures are sterile and systemic signs of infection have resolved.

4.2. Mechanical Failure and Over-Drainage

Mechanical shunt failure most commonly manifests as obstruction of the ventricular catheter by choroid plexus, blood, or debris, but valve and distal catheter obstruction also occur. Patients typically present with symptoms and signs of raised intracranial pressure and ventriculomegaly on neuroimaging [1–3,8]. In equivocal cases, shunt series radiographs, valve function testing, and shunt taps can help localize the site of failure.

Over-drainage can lead to subdural hygromas or hematomas, slit ventricle syndrome, and low-pressure headaches. Adults with NPH are particularly susceptible to subdural hematoma following rapid decompression. Programmable valves and gravitational or anti-siphon devices have reduced, but not eliminated, over-drainage complications. Initial high-pressure settings with gradual adjustment based on clinical and radiological response are commonly recommended, and higher opening pressures are often selected in elderly or anticoagulated patients to reduce subdural risk [1–3].

4.3. Early Abdominal Complications

Early abdominal complications include wound infection, seroma, hematoma, ileus, and intra-abdominal collections. Abdominal CSF pseudocysts may present early or late and are characterized by localized fluid collections around the distal catheter with symptoms such as abdominal pain, distension, or shunt malfunction [10–13]. Ultrasound and CT are useful for diagnosis. Management typically involves externalization or repositioning of the distal catheter, drainage of the pseudocyst, and treatment of any associated infection. Recent series support the feasibility of primary laparoscopic repositioning of the distal catheter in selected sterile pseudocysts, with acceptable recurrence rates [9–11].

5. LATE COMPLICATIONS (> 30 DAYS)

5.1. Distal Malfunction and Migration

Late mechanical failure is often related to distal catheter obstruction by omentum or adhesions, fracture or disconnection of the system, or progressive valve wear [1–3,8]. Migration of the distal catheter into the thorax, abdominal wall, scrotum, or hollow viscera has been reported. These events may present with subtle shunt malfunction, localized pain, or extrusion of the catheter. Radiographic evaluation with shunt series, ultrasound, or CT is essential for diagnosis, and management typically requires surgical revision with removal or repositioning of the affected components.

5.2. Late Infection and Abdominal Sepsis

Late-onset shunt infection may arise from hematogenous seeding during episodes of bacteremia, from chronic low-grade colonization of the system, or as a consequence of bowel perforation or other intra-abdominal pathology [6,7,10–13]. Clinical scenarios include recurrent low-grade shunt malfunction, abdominal pain with fevers, or unexpected growth of enteric organisms in CSF cultures. Management principles mirror those for early infection and emphasize complete shunt removal, control of the abdominal source (e.g., drainage, bowel repair, pseudocyst excision), and appropriately targeted antimicrobial therapy [6,7].

5.3. Recurrent Pseudocyst and Alternative Distal Sites

Recurrent or persistent abdominal pseudocyst raises the possibility of impaired peritoneal absorptive capacity, occult infection, or material hypersensitivity. In such cases, repeated attempts at peritoneal repositioning may be unsuccessful. A systematic review of sterile abdominal pseudocysts

found no clear superiority of distal catheter externalization versus peritoneal repositioning in terms of recurrence, with both strategies showing recurrence rates around 24–25% in long-term follow-up [8]. When peritoneal failure is evident, alternative distal drainage sites—including the right atrium (ventriculoatrial shunt) or pleural cavity (ventriculopleural shunt)—may be considered, each with its own risk profile [10–13]. Multidisciplinary discussion with pediatrics, cardiology, pulmonology, and infectious disease specialists is often required when deciding on alternative distal targets.

6. PREVENTION STRATEGIES: THE SHUNT BUNDLE

Given the multifactorial nature of VP shunt complications, prevention requires a standardized, systems-based approach rather than reliance on individual technical expertise alone. Building on successful quality-improvement initiatives in pediatric hydrocephalus, several groups have proposed and validated a "Shunt Bundle" —a set of evidence-informed measures designed to reduce infection and early failure [3–5,7,9]. Typical bundle components include:

- **Pre-operative optimization** and MRSA screening with targeted decolonization when appropriate.
- **Timely systemic antibiotic prophylaxis** and the routine use of antibiotic-impregnated catheters in high-risk patients [2–5,9].
- **Strict adherence to sterile technique**, double-gloving with glove change before handling shunt hardware, and use of standardized insertion checklists [4,5,9].
- Minimization of operating room traffic and handling of shunt components.
- **Consideration of image guidance** for proximal catheter placement in patients with small or distorted ventricles [1,8].
- Careful tunneling with sufficient subcutaneous length to reduce superficial contamination and wound breakdown.
- **Structured postoperative surveillance**, including early recognition and management of wound problems and shunt malfunction, and standardized pathways for evaluation of suspected infection [4,7–9].

Implementation studies from the Hydrocephalus Clinical Research Network and other consortia indicate that high compliance with such bundles can significantly reduce shunt infection and early revision rates,

often by 40–50% relative to historical controls [3–5,9]. They are therefore recommended as a core quality-improvement strategy in hydrocephalus care.

7. REVISION SURGERY AND LONG-TERM MANAGEMENT

Shunt revision surgery is indicated for confirmed mechanical obstruction, infection, over- or under-drainage that cannot be resolved by valve adjustment, and many abdominal complications [1–3,7–13]. When infection is present, staged management with complete explantation, temporary external CSF drainage, and delayed shunt re-implantation after CSF sterilization is the current standard of care [6,7]. In noninfectious failures, the choice between partial component replacement and complete system exchange depends on the etiology and the age of the shunt, but there is increasing evidence that more extensive revisions may confer superior long-term durability in selected patients with complex or multifocal failure patterns [1–3,8].

Lifelong follow-up is mandatory in both pediatric and adult hydrocephalus, as late failures and new complications may occur decades after the index procedure [1–3,8–13]. Structured follow-up plans that combine clinical assessment, imaging when indicated, and patient/caregiver education regarding warning signs are critical to timely recognition and management of shunt-related problems. Particular attention should be paid to high-risk groups such as infants, patients with prior shunt infections or multiple revisions, and those with complex abdominal histories.

8. NOVEL TECHNOLOGIES AND FUTURE DIRECTIONS

Advances in valve design, including gravitational and programmable systems, have already reduced the incidence of some over-drainage and under-drainage complications, though device-related failures remain common [1–3]. More recently, research has focused on "smart" shunt systems that incorporate telemetry-enabled intracranial pressure monitoring, flow sensors, or algorithms capable of automatic adjustment based on physiological signals. These technologies are still under evaluation, and cost-effectiveness remains uncertain, but they hold promise for reducing unnecessary revisions and improving long-term control of hydrocephalus.

In parallel, biomaterial science is exploring catheters with improved biocompatibility, reduced biofilm formation, and sustained antimicrobial properties. Meta-analyses of antibiotic-impregnated shunts and emerging data on silver- or hydrogel-coated devices illustrate both the potential benefits and the need for robust comparative trials [2,3,7,9]. Prospective registries and multicenter quality-improvement collaboratives are essential

to rigorously evaluate these innovations and ensure that they translate into meaningful reductions in shunt-related complications.

9. CONCLUSION

VP shunt surgery is indispensable but remains associated with a substantial burden of complications and revisions. Contemporary evidence confirms that infection and mechanical failure are the dominant drivers of morbidity, while abdominal complications, although less common, can be severe and challenging to manage [1–3,7–13]. A comprehensive understanding of risk factors, vigilant peri-operative care, and consistent use of standardized prevention bundles are central to improving outcomes. As technologies evolve, integrating smart systems and advanced biomaterials with rigorous quality-improvement initiatives offers the most promising path toward safer and more durable CSF diversion for patients with hydrocephalus.

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