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Review Article

Short review/perspective: Critical early treatment of infections including meningitis and/or ventriculitis due to recurrent postoperative lumbar cerebrospinal fluid leaks, lumbar drains, or intracranial devices/implants

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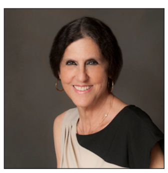

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ABSTRACT

Background: Early treatment of cerebrospinal fluid (CSF) infections, including meningitis and/or ventriculitis (MV) is critical to minimize morbidity/mortality. Infections/MV are typically attributed to; recurrent postoperative lumbar CSF fistulas with drainage through the skin (12.2-33.3%), lumbar drains, and/or various intracranial devices (i.e. external ventricular drains, intracranial pressure monitors).

Methods: Lumbar MR examinations best document recurrent postoperative dural fistulas with subcutaneous extension leading to leaking wounds; the longer these leaks persist, the greater the risk of CSF infection and MV. Classical cranial MR findings of MV due to prior lumbar surgery, lumbar drains or multiple intracranial devices include; ventricular debris, ependymal enhancement, hydrocephalus, extra-axial fluid collections, infarcts (arteritis/ventriculitis), abscesses, and granulomas.

Results: Surgery for recurrent postoperative lumbar CSF leaks typically warrant wound reexploration with direct sutured-dural repairs, use of muscle patch grafts (avoid fat – it resorbs), fibrin sealants/fibrin glues (FS/FG), lumbar drains, lumboperitoneal and/or pseudomeningocele-peritoneal shunts. For patients who additionally develop meningitis/ventriculitis, one should consider adding intraventricular (IVT) or lumbar intrathecal (IT) antibiotic therapy to routine intravenous antibiotics. Notably, all efforts should be made to avoid the high mortality rates associated with VM (i.e., 13% to 60%).

Conclusion: Recurrent postoperative lumbar CSF leaks (i.e., especially after CSF breaches the skin), lumbar drains, and/or intracranial devices/implants may cause infections including meningitis and ventriculitis (MV). It is critical to recognize and treat these infections/MV early to avoid high morbidity and mortality rates.

Keywords: Cerebrospinal Fluid (CSF) Leaks, Dural Repair, Early Diagnosis, Early Surgery, External Fistulas, External Ventricular Drains, Fibrin Sealant/Fibrin Glues, Infection, Intracranial Pressure Monitors, Lumbar Drain, Lumbar Surgery, Meningitis, Magnetic Resonance Imaging (MR), Muscle Patch Graft, Traumatic Dural Tears (DT), Ventriculitis

INTRODUCTION

Intraoperative cerebrospinal fluid leaks occur in 2-20% of primary lumbar operations, but this frequency markedly increases to 13.3% to 33.3% for recurrent lumbar/secondary surgery

Table 1: Infection, Meningitis, and/or Ventriculitis Due to Recurrent CSF Leaks After Lumbar Surgery, Lumbar Drains, or Cranial Implants/Procedures (i.e. EVD, ICP Monitors, Other).

Author [Reference] Journal Year	Study Design	Variables	Variables	Variables	Conclusion
Kanamalla Neuro-imaging Clin N Am 2000	Infections Cause MR Changes of Cerebral Meninges	Contrast MR Shows Fluid+Attenuated Inversion-Recovery MR	MR Superior to Contrast CT Exams for Diagnosing Meningitis	Meningitis AE: HC Extra-Axial Mass, Infarcts (Arteritis), Ventric Abscess Granulomas	Early Diagnosis of Meningeal Inf with MR+Contrast Decreases M & M
Fukui AJNR Am J Neuoradiol 2001	17 Cases Pyogenic Ventric+ 3 Abscesses +Cultures >WBC >Protein 12 Ventric 1 Cisternal, 1 Lumbar CSF	Most Org Staphylococcus Enterobacter 16 Studies 11 IV Contrast	2 Reviewers Neurorad HC. Ventric Debris, Periventric Abnormality EpendEnh Meningitis Abscess	MR: 16 Ventric Debris 13 Irregular Periventric 13 HC 7 Periventric Hyperintense 7 EpendEnh	13 Meningitis (Pial/ Dura-Arachnoid Signal Enh) 3 Abscesses Most Ventric Debris -Less HC/EpendEnh
Deen HG Surg Neurol 2003	4 Pts CSF Leaks PseudoM Postop Lumbar OR	LumP Shunt VLapAssist Ref Leaks to DirRep, ExtDr BloodP	CSF Leak PseudoM Diversion Lum Spine-Perit	1st LumP Shunt 2nd PseudoM -Perit Shunt No Bed Rest No Drains	Pros Shunts <Procedures <LOS >Accurate Placement <OR Time
Remes J Neuorsurg 2013	34 IVT or Lumbar IT Antib Postop NSGY Pts with MV Sterilize CSF 2.9 d +/- 2.7 d drain 1-12 d CSF Neg in 24 h with IVT/IT Antib 17 (50%) pts+Up to 48 hrs 6 (18%) pts	Outcomes Modified Rankin Scale Imp 17 (50%) No Chg 10 (29%) 1 Poor 3% 6 Died Mortality Rate 11.8% (some Other Causes)	All 4 Ventric Rx IVT Antib Sterile Avg CSF 6.5 d; 30 Mening no Ventric LD Gram Neg; Sterile CSF 2.2 d (vs. External Ventric Drain 2.6 d)	AE - IVT/IT 3/34 Low Clinical Sig. 30 IT Lumbar Mening no Ventric; More Gram Neg; Sterile CSF 2.2 d (vs 2.6 d VDrain Few AE with IVT/IT	IVT/IT Lumbar Antib Rapid CSF Sterility After OR NSGY Low Relapse Rates
Woodroffe Clin Neurol Neurosurg 2018	Iatrogenic CSF Leaks 124/3965 (3.1%) Literature CSF 1st Intraop Leaks 2-20%	64 Primary Repair 1st OR Success 73.4% vs. 49 LD +/- Primary 1st Closure Success 87.8%	34 Delayed Exploration No Primary Repair/ No LD Reexplore Rate 39.5%	Delayed Exploration Longer LOS (19.6 vs 7.8 d), >Admit 2.1 vs. 1.0, >Inf Rate 15 vs. 0 AE for CSF Leaks 27.4%	Advocate Primary DT Repair+Fibrin Sealant+LD <LOS, <Readmit <Reop Rate <Inf
Lewin Neurocrit Care 2019	105 Pts ICU IntraVent Antib Rx MV High Sterilization Multicenter	All IV Antib+IntraVent Rx 2003-2013	IntraVent Vanco 52.4% 12.2 mg/d for 5 d	IntraVent AminoGl 47.5% +/- IV Vanco 6.7 mg/d for 6 d	Mortality MV 18.1% CSF Sterile in 88.4% Recurrent or Persistent Inf In 9.5%
Hussein Acta Neurochir (Wien) 2019	RF Inf MV NSGY 232 Pts/437 Drains/ Cath	Inf Rate 13.7 per 1000 Drain d -Gram Neg Bacteria Most	RF Inf DM, CSF Leak, More Drain Opening, Most Drain Duration	Major RF Drains: Opening Drain, # Days	Main RF Drains >Drain Days >Opening <Duration

(Contd...)

Table 1: *(Continued).*

Author [Reference] Journal Year	Study Design	Variables	Variables	Variables	Conclusion
	EVD (212) LD (92) ICP (133)	Acinetobacter Baumani			
Aspalter Front Surg 2021	ADT MIS Lumbar Surgery	187 Pts Deg. Lum Surg MIS 22 Traumatic ADT (11.8%) Bed Rest 2.5-5 d	RF DT Not Increased with Age, >BMI Smoking, DM	>Risk ADT- Prior OR Series Included No Postop CSF Leaks Through Skin/ No Inf	Incidence ADT with MIS Similar to Open Surgery <PseudoM <Dead Space
Luque-Paz Open Forum Infect Dis 2021	98 Pt Ventric NSGY 42 F, 56 M Avg Age 60 Score Risk 1 yr Mortality Low 12.5% Int 36.5% High 71.4%	Etiology BAb 29.6% Mening 27.6 IntraVent Cath 17.3% Post NSGY 13.3% Hematog 12.2%	Imaging IntraVent Pus 82.7% EpendEnh 71.4% IntraVent Loculations 15.3%	Organisms Strep 44.9% Gram Neg 27.6% Staph 15.3% Inhospital Mortality 30.6% 1 yr 38.8% Mortality	Neuro Deficits 61.8% 1 Cognition 9 Gait 7 Paresis 5 Seizures 6 Behavior RF Mortality 1 yr : Age >65, GCS >13, SEpil, HC+CSF Culture
Coelho Cureus 2021	Healthcare Associated MV N-CC >>Mortality	Infection MV Largely Due to OR Using Intracranial Devices	3 yrs-218 N-CC pts: MV 13% High Mortality	30% Hard to Diagnose MV	Signs MV Sustained >Fevers >CSF >Cell Count
Karyouniaris Infect Drug Resist 2022	Diagnosis Manage Ventric Mening (MV)	Postop NSGY Devices, Cath, Drains Add to M&M for MV	Most Gram Negative Bacteria Skin Flora Nosocomial Pathogens	Difficult to Treat; Direct Installation in CSF/IV Antibiotics (IVT) for Inf	AE IVT Antibiotics Seizures Aseptic Meningitis Biofilm -Cath, Vent Endoscopy
Ippolito Curr Opin Anaesthesiol 2022	Health-Care Associated CNS Infection	High Index Suspicion Infection RF Recent NSGY, CSF Shunts, Drains, Implantable Devices, Trauma	Diagnostic Challenges Reduced LOC/Coma	Gram Negatives Gram Positives Often Multiple Resistant Check CNS Penetrance	Ineffective Treatment Mortality Reaches 60%
Lilley Infect Prev Pract 2022	Analysis Manage Ventric UK NSGY Centre Guidelines to Treat V Antib+Device Remove	Organisms Coag Neg Staph, Gram Neg, Gram Pos Bacteria 2009-2019	Etiology CSF Shunts EVD 99 pts Ventric 105.98% Devices-Best Remove for Care	Most Wrongly Used Antib Meropenem+ Linezolid Cost Pounds 201,172 over 10 yrs	Most Organisms Coag Neg Staph Mortality 14% Ventric
Li Neurocrit Care 2024	Early IVT Antib Rx In Hospital <Mortality Neuro Critical Care Drug Resistant MV	HospAqc MDR Bacterial MV >Mortality RF 2003-2021 142 Pts IV Antib; 102 Also IVT Antib	Rx IVT 3 d Higher CSF Sterilization Rate 81.5% Start IVT 2 d (rg 1-5 d) Shorter Time Sterility 7 d	vs. Delay IVT >3 d 48.5 Sterile at 11.5 d Vs Sys Antib 42.5 Sterile 10 d	Early IVT Antib Better Outcomes <Morality >Rapid+ >Rate Sterilize CSF

(Contd...)

Table 1: *(Continued).*

Author [Reference] Journal Year	Study Design	Variables	Variables	Variables	Conclusion
Epstein Surg Neurol Int 2024	Timely Diagnosis-Repair CSF T/L Leaks Primary DT 2.6-8% Delayed Leak 0.83% (17/2052) to 14.3% (2/14)	Recurrent Postop CSF Leaks 13.3% (2/15) to 33.3% (4/12) pts 1st Surgery: Sufficient Exposure	CSF Leak Repair: Microscope Interrupted Non-absorbable 7-0 Gore-Tex Suture/ Patch Muscle Grafts	CSF Leak Repair Micro-fibrillar Collagen, Fibrin Sealant (FS) Fibrin Glue (FG) Lumbar Drain (LD), LP Shunts	OR Success Adequate Exposure Microscope Interrupted Sutures, Muscle Grafts/FS/FG/LD Microfibrillar Collagen , LP Shunts

Postop=Postoperative, CSF=Cerebrospinal Fluid, AE=Adverse event, TSP=Transsphenoidal, Surg=Surgery, Men=Meningitis, Vent=Ventriculitis, Preop=Preoperative, EEN=Endoscopic/Endonasal, Comorb=Comorbidities, , BMI=Body Mass Index, CNS=Central Nervous System, Inf=Infection, Reop=Reoperation, LD=Lumbar Drain, NSGY=Neurosurgery, ICP=Intracranial Pressure, Monit=Monitoring, RF=Risk Factors, Cath=Catheters, EVD=External Ventricular Drainages, Gram Neg=Gram Negative, Gram Pos=Gram Positive, DM=Diabetes, ICP=Intracranial Pressure, Sig=Significant, LP/LumP=Lumboperitoneal, Shunt=Shunting, VLapAssist=Video-Laparoscopic Assisted, Lum=Lumbar, PseudoM=Pseudomeningocele, Ref=Refractory, Pseudo=Pseudomeningocele, DirRep=Direct Repair, ExtDr=External Drainage, BloodP=Blood Patches, Perit=Peritoneum, Pts=Patients, LOS=Length of Stay, OR=Operative, M&M=Morbidity/Mortality, VM or MV=Ventriculitis/Meningitis, Rx=Treat, IntraVent=Intraventricular, Vent=Ventricular, Antib=Antibiotics, ICU=Intensive Care Units, IV=Intravenous, AminoGl=Aminoglycosides, d=Days, AE=Adverse Events, CNS=Central Nervous System, Ventric=Ventriculitis. F=Females, M=Males, Mening=Meningitis BAb=Brain Abscess, Hematog=Hematogenous, EpendEnh=Ependymal Enhancement, yr=Year, NeuroImp=Neurological Impairment, SEPil=Status Epilepticus, HC=Hydrocephalus, GCS=Glasgow Coma Score, Int=Intermediate, HospAcq=Hospital Acquired, MDR=Multi Drug Resistant, IVT=Intraventricular Therapy (Antibiotics), Sys=Systemic, IT=Intrathecal (Lumbar Administered), Imp=Improved, VDrain=Ventricular Drain, LOC=Level of Consciousness, N-CC=Neuro Critical Care Patients, UK=United Kingdom (England), Coag=Coagulation, Neg=Negative, Staph=Staphylococcus, EVD=External Ventricular Drains, Org=Organisms, Neurorad=Neuroradiologists, Enh=Enhancement, Irreg=Irregular, DT=Dural Tear. MIS=Minimally Invasive, DLS=Degenerative Lumbar Surgery, ADT=Accidental Dura Tears, T/L=Thoracolumbar, FS/FG=Fibrin Sealants/Fibrin Glue, rg=Range

[Table 1].[1,4,15] Early diagnosis with MR and early surgery for postoperative recurrent fistulas (i.e. before CSF breaches the skin) are critical to reduce the risk of infection, including meningitis, and/or ventriculitis (VM) which can prove fatal.[4,5,8,14] Surgical options include; reexploration with direct repair of dural tears (DT), the addition of muscle patch grafts (avoid fat-it resorbs), the application of fibrin sealants/ fibrin glues (FS/FG), the placement of external lumbar drains (LD), and/or shunts (i.e. lumboperitoneal and/or pseudomeningocele-peritoneal shunts).[3,4,6,15] For meningitis/ ventriculitis, routine systemic intravenous antibiotic therapy should likely be supplemented with timely intraventricular (IVT) or lumbar intrathecal (IT) antibiotics in an attempt to reduce the VM mortality rates ranging from 13%-60%.[2,7,9,10-14]

Incidence of Primary and Recurrent CSF Leaks with Lumbar Surgery

The risks of intraoperative cerebrospinal fluid leaks occurring during primary lumbar surgery ranges from 2-20%; notably, the rates for recurrent postoperative/secondary leaks is even higher ranging from 13.3% to 33.3% [Table 1].[1,4,15] In Woodroffe *et al*. (2018) iatrogenic primary lumbar surgical CSF leaks occurred in 3.1% of patients (i.e., 124 of 3965 cases); 73.4% of 64 CSF leaks were effectively primarily repaired, while 87.8% of 49 patients were successfully managed with primary closure and the addition of lumbar drains.[15] They also observed that delayed reexplorations resulted in longer lengths of stay, higher readmission/reoperation/infection rates, and more overall adverse events. For Asplater *et al*. (2021) 11.8% of 187 patients undergoing minimally invasive lumbar surgery (MIS) had primary iatrogenic acute dural tears; however, in this series, as no CSF leaks breached the skin, there were no infections.[1] Interestingly, their incidence of primary MIS surgical CSF leaks was comparable to those for open procedures. In 2024, Epstein's review showed a 2.6-8% incidence of primary lumbar CSF leaks, while postoperative recurrent/secondary fistulas occurred in a higher 0.83%-14.3% of patients.[4]

MR Diagnosis of Recurrent Postoperative/Secondary CSF Leaks Resulting in Infections Including Meningitis and Ventriculitis (MV)

MR studies with/without contrast are superior to CT examinations in identifying postoperative lumbar wound infections, including documenting meningitis and/or ventriculitis (MV) [Table 1].[5,8,13] Kahamalla *et al*. (2000) described the efficacy of MR studies with/without contrast as capable of demonstrating fluid contiguous with the dura, and extending through the paraspinal soft tissues into the subcutaneous compartment.[8] They emphasized how critical it was to diagnose meningitis early as it could devolve into; hydrocephalus (i.e. noting that this could develop/be exacerbated particularly once external drainage was stopped (lumbar wounds repaired) and/or devices were removed), extra-axial masses, infarcts (arteritis, ventriculitis), abscesses, and granulomas, resulting in significant morbidity and mortality. In 2001, Fukui *et al*. (2001) emphasized the classical MR findings for pyogenic ventriculitis in 17 patients; 16 had ventricular debris, 13 exhibited periventricular irregularities, 13 had hydrocephalus, while other findings included; ependymal enhancement, meningitis, and/or abscess formation.[5] Further, Luque-Paz *et al*. (2021) treated 98 patients with ventriculitis including the 13.3% attributed to prior neurosurgical procedures; here, MR showed intraventricular pus in 82.7%, ependymal enhancement in 71.4%, and intraventricular loculations in 15.3% of patients.[13]

Recommendations for Treating Primary or Recurrent Postoperative Lumbar CSF Leaks

Two lumbar studies cited multiple surgical options for repairing primary, delayed, and/or recurrent postoperative CSF leaks [Table 1].[3,4] Deen *et al*, (2003) treated 4 postoperative pseudomeningoceles using video-laparoscopy to place both (1) lumboperitoneal, and (2) pseudomeningocele-peritoneal shunts.[3] They claimed these combined procedures resulted in fewer reoperations/procedures (i.e. direct repairs, extended drainage, use of blood patches), shortened lenth of stay, results in more accurate shunt placement, and reduced operative times. For repairs of recurrent/secondary CSF leaks, Epstein (2024) advocated using an operating microscope, and combinations of non-resorbable 7-0 Gore-Tex interrupted sutures (running sutures more likely to fail/unfurl), muscle patch grafts (avoid fat-it resorbs), microfibrillar collagen, and fibrin sealant/fibrin glues (FS/FG).[4] In Epstein's experience, only complex recurrent leaks warranted the placement of lumbar drains and/or lumboperitoneal shunts.

Treatment of Infections Including Use of IVT/IT Antibiotics for Treating Meningitis and Ventriculitis Attributed to Recurrent Postoperative Lumbar CSF Leaks, Lumbar Drains, and/or Intracranial Devices

Recurrent/secondary postoperative lumbar CSF leaks involving skin breaches and other (i.e. lumbar drains, intracranial drains/devices) causes of infections leading to MV require varied systemic and IVT/IT antibiotic regimens [Table 1].[6,10,14] In Remes *et al*. series of 34 patients, mostly gram negative organisms caused wound infections/MV and required IVT/IT antibiotics.[14] For Lewin *et al*. (2019), of 105 ICU patients receiving IVT antibiotics for VM, 52.4% received Vancomycin, while 47.5% had IVT Aminoglycosides; 88.4% with both meningitis and ventriculitis achieved achieved CSF sterilization adding IVT with I VT Aminoglycosides vs. 9.5% with recurrent or persistent postoperative infections.[10] For the 232 out of 437 neurosurgical patients who developed drain-related meningitis/ventriculitis due to the placement of EVD, LD, and ICP monitors in Hussein *et al*. (2019) series, the main offending organism was Acinetobacter Baumannii.[6]

Mortality Rates for Meningitis/Ventriculitis Attributed to Postoperative Lumbar Recurrent CSF Leaks, Lumbar Drains, or Intracranial Devices/Implants

Varied high mortality rates (i.e.11.8% to 60%) were cited for patients with MV attributed to recurrent postoperative/secondary lumbar CSF leaks, lumbar drains, or intracranial devices [Table 1].[2,10,12-14] For the 34 patients with MV treated with IVT/IT in Remes *et al*. series (2013), the mortality rate was 11.8% (i.e., however, the authors noted some of these some patients died from other causes).[14] There was a 18.1% mortality rate in Lewin *et al*. (2019) series of 105 MV patients undergoing IVT antibiotic treatment.[10] When Luque-Paz *et al*. (2021) treated 98 patients with ventriculitis, 13.3% of whom had previously undergone neurosurgical procedures, the overall mortality rate was 30.6%.[13] They found the in-hosptial 1 year mortality rate was 38.8%, and was associated with the following major risk factors; age over 65, Glasgow Coma score of > 13, Status Epilepticus, Hydrocephalus (i.e. developing concurrent with active lumbar CSF leaks/external drainage or in a delayed fashion once lumbar fistulas were repaired and/or after drains were removed), and positive CSF Cultures. Over 3 years, Coelho *et al*. (2021) found a 13% mortality rate among 218 neurosurgical patients with MV due to various intracranial devices.[2] Ippolito *et al*. (2022) recognized that MV infections could be attributed to neurosurgical CSF shunts, drains, implantable devices, and/or trauma, resulting in up to 60% mortality rates.[7] Lilley *et al*. (2022) observed a 14% mortality rate from ventriculitis that occurred in 99 patients treated with 105.90% ventricular devices (i.e. CSF shunts, external ventricular drains (EVD), and others).[12]

Treat Infections/MV Attributed to Recurrent Lumbar CSF Leaks, or Lumbar/Intracranial Implants with Intraventricular (IVT) or Lumbar Intrathecal (IT) Antibiotics

Several studies reviewed the diagnosis and treatments of CSF infections/MV attributed to recurrent postoperative lumbar CSF fistulas, or the placement of Lumbar Drains (LD), Intracranial External Ventricular Drains (EVD), or Intracranial Pressure Monitors (ICP) [Table 1].[2,6,7,9,11-13] Remes *et al*. (2013) 34 patients with MV (i.e. 30 meningitis alone; 4 meningitis/ventriculitis) received IVT or IT (i.e. using a lumbar drain) antibiotics; CSF was sterilized within an average of 2.9 days; the CSF cultures were negative within 24 h with IVT/IT in 17 (50%) of patients, and in up to 48 hours for another 6 (18%) patients.[14] Outcomes using the Modified Rankin Scale showed; improvement in 17 patients (50%), no change 10 patients (29%), 1 poor result (3%) and 6 deaths. They concluded IVT/IT resulted in rapid sterilization of CSF for patients with MV. In Hussein *et al*. (2019), 232 out of 437 neurosurgical patients developed drain-related meningitis/ventriculitis attributed to EVD, LD, and ICP monitors; the infection rate was 13.7 per 1000 drain days, and the predominant organism was Acinetobacter Baumannii.[6] Risk factors for MV included; diabetes and external CSF leaks, with the most prominent factor including the frequency of drain opening, and longer duration of drain use; ultimate recommendations included shorter duration of drainage with fewer openings. Luque-Paz *et al*. in 2021 had 98 patients with ventriculitis variously attributed to; 13.3% neurosurgical procedures; 20.6% after treatment of brain abscess, 27.6% with meningitis, and 7l% with intraventricular catheters.[13] They identified the following organisms; Streptococcus 44.9%, Gram Negatives 27.6%, and Staphylococcus 15.3%). Ultimately, 61.8% ended up with residual neurological deficits that included; 9 with gait disturbance, 7 with paresis, 5 with seizures, and 6 with behavioral and/or cognitive changes. Coelho *et al*. (2021) diagnosed 218 VM infections over 3 years in patients with various intracranial devices exhibiting persistent fevers, and high CSF cells counts.[2] Karyouniaris *et al*, (2022) diagnosed VM in post neurosurgery patients, and managed them with IVT (i.e. they had imlanted devices including catheters and drains); most infections were due to Gram Negative bacteria (i.e., skin flora, or other nosocomial pathogens).[9] They did observe the following risk factors associated with using IVT; seizures, aseptic meningitis, and biofilm on implanted catheters prolonging or increasing the risks of persistent infection. Ippolito *et al*. (2022) recognized that VM could develop due to various neurosurgical devices (i.e. CSF shunts, drains, implantable devices, and after trauma); notably, once external drainage of CSF was occluded (i.e. lumbar wounds repaired or lumbar drains/EVDs removed) patients who had developed underlying hydrocephalus often subsequently required placement of ventriculoperitoneal or lumboperitoneal shunts. Organisms identified typically included. Gram Positives, and only rarely, were multiple resistant organisms encountered.[7] Lilley *et al*. (2022) analyzed 99 patients with 105.90% ventricular devices (i.e., due to CSF shunts, EVD and others), and advocated, IVT with device removal.[12] The most common organisms were Coagulase Negative Staph, Gram Negative Bacteria, or Gram Positive Bacteria. Typically, the wrong antibiotics were being given (Meropenem and Linezolid). Li *et al*. (2024) recommended early IVT antibiotic installation to reduce in-hospital mortality due to MV; IVT was additionally given to 102 of 142 patients with MV receiving systemic antibiotics.[11] This resulted in higher rates and shorter times to sterilization of CSF, better outcomes, and lower mortality rates.

CONCLUSION

CSF infections resulting in meningitis/ventriculitis may be attributed to recurrent postoperative lumbar CSF leaks (i.e., ideally prior to CSF breaching the skin), lumbar drains, and/or cranial implants/devices. Early diagnosis and treatment of these infections/MV will likely reduce their accompanying high morbidity and mortality rates.

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