

Original Article

Post-neurosurgical meningitis: Management of cerebrospinal fluid drainage catheters influences the evolution of infection

Laura Soavi, Manuela Rosina, Roberto Stefani¹, Alessia Fratianni², Barbara Cadeo, Silvia Magri, Nicola Latronico³, Marco Fontanella², Liana SignoriniClinic of Infectious and Tropical Diseases, ²Department of Neurosurgery, ³Department of Anesthesia, Critical Care and Emergency, Spedali Civili Hospital, Brescia, ¹Department of Neurosurgery, ASST – Ovest Milanese, Legnano, ItalyE-mail: Laura Soavi - laura.soavi@gmail.com; Manuela Rosina - manuelarosina@hotmail.com; Roberto Stefani - roberto.stefani@gmail.com; Alessia Fratianni - alessia.fratianni@yahoo.com; Barbara Cadeo - barbara.bs@libero.it; Silvia Magri - silviamagri@bresciaonline.it; Nicola Latronico - nicola.latronico@unibs.it; Marco Fontanella - marco.fontanella@unibs.it; *Liana Signorini - l.signorini@infettivibrescia.it
*Corresponding author

Received: 10 July 16 Accepted: 01 October 16 Published: 05 December 16

Abstract

Background: In order to better define the pathogenic role of cerebrospinal fluid (CSF) drainage catheters in postoperative patients, we comparatively analyze the clinical course of device and non-device-related meningitis.**Methods:** This is an observational, partially prospective, study on consecutive adult patients who developed meningitis after undergoing neurosurgical procedures at the Neurosurgery and Neurointensive care Departments, Spedali Civili, Brescia, Italy, between January 1999 and August 2007.**Results:** All 77 consecutive post-neurosurgical meningitis events in 65 patients were included in the analysis. Most were classified as external ventricular drainage (EVD)-related meningitis (23 cases, group A), external spinal drainage (ESD)-related meningitis (12 cases, group B), and non-device-related post-neurosurgical meningitis (30 cases, group C). Proven meningitis was identified in 78.3%, 91.7% and 56.7% of the events, respectively. ESD-related meningitis had a shorter onset time vs EVD and non-device-associated meningitis (3 days *versus* 6 and 7 days, respectively). Median antibiotic treatment duration was 20, 17, and 22.5 days in groups A, B, and C, respectively. Overall, 8 patients (34.8%) in group A, 3 (25.0%) in group B, and 3 (10.0%) in group C died. Median time to become afebrile was shorter in group C than in group A (10 days *versus* 12 days, $P = 0.04$). Removal of the device later than 48 hours after meningitis onset, as well as implantation of a second device were associated with a slower time of meningitis resolution.**Conclusions:** Early device removal and avoiding implantation of a second device were associated with short illness duration. Larger studies are warranted to confirm the conclusions of this study.**Key Words:** Cerebrospinal fluid drainage catheters, meningitis, neurosurgery**Access this article online****Website:**www.surgicalneurologyint.com**DOI:**

10.4103/2152-7806.195228

Quick Response Code:

This is an open access article distributed under the terms of the Creative Commons Attribution-NonCommercial-ShareAlike 3.0 License, which allows others to remix, tweak, and build upon the work non-commercially, as long as the author is credited and the new creations are licensed under the identical terms.

For reprints contact: reprints@medknow.com**How to cite this article:** Soavi L, Rosina M, Stefani R, Fratianni A, Cadeo B, Magri S, et al. Post-neurosurgical meningitis: Management of cerebrospinal fluid drainage catheters influences the evolution of infection. *Surg Neurol Int* 2016;7:S927-34.<http://surgicalneurologyint.com/Post-neurosurgical-meningitis-Management-of-cerebrospinal-fluid-drainage-catheters-influences-the-evolution-of-infection/>

INTRODUCTION

Postoperative meningitis is a rare but serious complication of neurosurgery. In clean neurosurgery, the rate of postoperative bacterial meningitis is low (1–2%).^[9] The use of devices for therapeutic drainage of cerebrospinal fluid (CSF) or for intracranial pressure monitoring, such as external ventricular drains (EVD), external spinal drains (ESD), and shunts, is associated with an increase in the rate of postoperative meningitis of up to 22%.^[3,9] Meningitis may lead to worsened outcome, including increased mortality, prolonged hospital stay, repeat surgery, and increased hospital costs.^[2,10,11,14]

There is a large body of evidence regarding postoperative meningitis in terms of risk factors, pathogenesis, and microbiological aspects.^[1-3,7-11,14] In contrast, little is known about the clinical course of postoperative meningitis; data concerning the time of symptom resolution and CSF parameters normalization are limited. Furthermore, there are no set guidelines on how to manage post-neurosurgical infections, especially in the presence of a device.

We performed an observational study of all consecutive cases of postoperative meningitis observed in adults at a tertiary hospital in Northern Italy to compare outcome and clinical evolution, including laboratory and microbiological parameters, of device (EVD and ESD-related) and non-device-related meningitis.

MATERIALS AND METHODS

Hospital setting

The study was conducted at the Department of Neurosurgery and Neurointensive care of Spedali Civili, Brescia, Italy. An intensive infectious diseases consultation program, with ≥ 3 consultations per week, has been ongoing since 1999.

Study population and data collection

We included all consecutive cases of postoperative meningitis observed between January 1999 and August 2007 in patients over 18 years of age. Data were collected retrospectively until June 2004 and prospectively thereafter. During the retrospective phase, episodes of meningitis were identified using the electronic register, identifying cases of meningitis from the discharge diagnosis and/or from the infectious diseases consultation records, and relevant medical charts were reviewed. The protocol for perioperative antibiotic prophylaxis consisted of cephazoline 2 g intravenously half an hour before surgery followed by 1 g after 3 hours, if the duration of the intervention exceeded 3 hours.

During the prospective phase, each episode was evaluated by infectious diseases consultants according to the predefined criteria (see below), and data was actively collected on ad-hoc charts. To evaluate the influence

of neurosurgical devices on meningitis evolution and outcome, statistical analysis was performed to compare patients with EVD, with ESD, and without any device.

Case definitions

Proven meningitis was defined as a positive CSF culture and laboratory CSF findings of a neutrophilic CSF pleocytosis (>5 cells/ μ L) and a CSF/blood glucose ratio of <0.5 along with meningitis signs and/or symptoms [fever, headache, neck stiffness, cranial nerve signs, or Glasgow coma scale (GCS) worsening].

Possible meningitis was defined by laboratory CSF findings of a neutrophilic CSF pleocytosis (>5 cells/ μ L) and a CSF/blood glucose ratio of <0.5 along with meningitis signs and/or symptoms with a negative CSF culture.

Patients with postoperative, non-device-related meningitis were included if neurosurgery had been performed 3 months or less prior to meningitis onset. Patients with postoperative device-related meningitis were included if the neurosurgical device was in place at meningitis onset.

Fever clearance ($T \leq 37^\circ\text{C}$) was utilized to evaluate clinical response to therapy. Blood and CSF samples were periodically collected to evaluate improvement time (time from onset to the second consecutive improved measurement) and normalization of the following parameters: Blood/CSF leucocyte count and CSF glucose level.

Statistical analysis

Student's *t*-test was used to compare means and a Chi-square test was used to compare proportions. Continuous variables were compared using the Wilcoxon rank-sum test. A *P* value of 0.05 was considered to be statistically significant. A multivariate logistic regression model was fitted to the data to identify potential factors related to the outcome. All calculations were performed using the Stata version 13 software (StataCorp. 2013. Stata Statistical Software: Release 13. College Station, TX: StataCorp LP)..

RESULTS

During the study period, 77 events of postoperative meningitis were identified among 65 patients. Description of the study population is shown in Table 1. There were 47 events of device-related meningitis (23 EVD, 12 ESD, 7 ventriculoperitoneal shunts, 2 intracranial pressure devices, and 3 subarachnoid catheters), and 30 non-device-associated events. Patients with EVD-related meningitis were defined as group A, those with ESD-related meningitis as group B, and those with postoperative, non-device-related meningitis as group C.

Emergency surgery was performed in 14 patients (60.9%) in group A, 3 (25.0%) in group B,

Table 1: Demographic and clinical characteristics of the study population

Variable	Group A (n=23)	Group B (n=12)	Group C (n=30)	P
Male gender, no. of patients (%)	17 (73.9)	6 (50.0)	20 (66.7)	NS
Age in years, median (range)	48 (21-79)	61 (22-75)	52.5 (18-80)	NS
Comorbidities, no. of patients (%)				
None	15 (65.2)	9 (75.0)	16 (53.3)	NS
Cardiovascular diseases	6 (26.1)	2 (16.7)	9 (30.0)	
Diabetes mellitus	1 (4.4)	0 (-)	4 (13.3)	
COPD	1 (4.4)	0 (-)	2 (6.7)	
Chronic renal failure	1 (4.4)	0 (-)	0 (-)	
Tumors	2 (8.7)	0 (-)	0 (-)	
Hemopathies	0 (-)	0 (-)	1 (3.3)	
Others	0 (-)	1 (8.3)	4 (13.3)	
Risk factors, no. patients (%)				
None	15 (65.2)	8 (66.7)	20 (66.7)	0.009 (A vs B)
Immunosuppressive therapy	1 (4.4)	0 (-)	0 (-)	
Alcoholism	3 (13.0)	0 (-)	0 (-)	
Surgery <3 months	2 (8.7)	4 (33.3)	5 (16.7)	
Extra-CNS infections <3 months	0 (-)	4 (33.3)	4 (13.3)	
CNS infections <1 years	3 (13.0)	4 (33.3)	4 (13.3)	
CSF leak	0 (-)	0 (-)	3 (10.0)	
MDR bacteria colonization	1 (4.4)	1 (8.3)	1 (3.3)	
Neurosurgical conditions, no. of patients (%)				
Subarachnoidal bleeding	4 (17.4)	0 (-)	1 (3.3)	0.05 (A vs C)
Intraventricular hemorrhage	5 (21.7)	3 (25.0)	1 (3.3)	
Intracerebral hemorrhage	4 (17.4)	4 (33.3)	7 (23.3)	
Head trauma	1 (4.4)	0 (-)	1 (3.3)	
Post-traumatic hydrocephalus	3 (13.0)	0 (-)	1 (3.3)	
CNS tumor	2 (8.7)	1 (8.3)	5 (16.7)	
Hydrocephalus	2 (8.7)	2 (16.7)	2 (6.7)	
Intracerebral abscess	0 (-)	0 (-)	2 (6.7)	
Intracerebral device infection	1 (4.4)	1 (8.3)	0 (-)	
Others	1 (4.4)	1 (8.3)	10 (33.3)	
Preoperative ASA score, no. patients (%)				
<3	5 (21.7)	4 (33.3)	10 (33.3)	NS
≥3	5 (21.7)	5 (41.7)	6 (20.0)	
Unknown	13 (56.5)	3 (25.0)	14 (46.7)	
Preoperative GCS score, no. patients (%)				
≤10	11 (47.8)	5 (41.7)	8 (26.7)	NS
>10	9 (39.1)	4 (33.3)	11 (36.7)	
Unknown	3 (13.0)	3 (25.0)	11 (36.7)	

Group A: Patients with EVD-related meningitis, Group B: Patients with ESD-related meningitis, Group C: Patients with postoperative non-device-related meningitis, NS: Non-significant

and 8 (26.7%) in group C ($P = 0.03$ for A vs C). Median duration of surgery in groups A, B, and C was, respectively, 85 (range: 15–360), 180 (range: 20–300), and 180 minutes (range: 60–990). Among patients who were not receiving antibiotic therapy at the time of neurosurgery, antibiotic prophylaxis was appropriately prescribed in, respectively, 6/16 (37.5%), 3/9 (33.3%), and 10/27 patients (37.0%). Eleven patients (47.8%) in group A, 5 (41.7%) in group B, and 12 (40%) in group C

experienced postoperative complications (mainly CSF leakage and relapse of intraventricular hemorrhage). No statistically significant differences were found in length of surgery, appropriateness of prophylaxis, and frequency of postoperative complications among the three groups.

Table 2 summarizes the major features of neurosurgical devices. Among 465 EVDs implanted during the study

period, the overall EVD-related meningitis rate was 4.9%, with large variability per year (0–14%).

Variables related to meningitis clinical presentation and blood/CSF chemistry at meningitis onset are summarized in Table 3.

Meningitis was proven in 18 (78.3%), 11 (91.7%), and 17 (56.7%) in groups A, B, and C, respectively. Among patients for whom CSF culture yielded negative results (5 patients in group A, 1 in group B, and 13 in group C), 2 patients in group A and 4 in group C were on antibiotic therapy

Table 2: Main characteristics of the neurosurgical devices

Variable	Group A (n=23)	Group B (n=12)	Group C (n=30)	P
Time to meningitis onset, median days (range) (since DVE/DSE positioning-group A and B-or since neurosurgery-group C)	6 (0-28)	3 (0-20)	7 (1-99)	0.07 (B vs C)
Time to device removal, median days (range) (since meningitis onset)	6 (0-30)	4 (0-17)	-	NS
Device 2, no. of patients (%)				NS
Shunt	2 (8.7)	0 (-)	-	
EVD	6 (26.1)	3 (25.0)	-	
ESD	6 (26.1)	1 (8.3)	-	
Time to device 2 removal, median days (range) (since device 2 positioning)	10.5 (2-32)	11 (3-68)	-	NS

Group A: Patients with EVD-related meningitis, Group B: Patients with ESD-related meningitis, Group C: Patients with postoperative non-device-related meningitis, Device 2: Second neurosurgical device implanted (due to hydrocephalus) during meningitis course, NS: Non-significant

Table 3: Clinical characteristics and blood/CSF chemistry at meningitis onset

Variable	Group A (n=23)	Group B (n=12)	Group C (n=30)	P
Clinical characteristics				
Fever	19 (82.6)	12 (100)	27 (90)	NS
Headache	2 (8.7)	3 (25)	11 (36.7)	0.02 (A vs C)
Neck stiffness	3 (13)	2 (16.7)	9 (30)	NS
Decrease in GCS	2 (8.7)	3 (25)	7 (23.3)	NS
Vomiting	1 (8.3)	1 (3.3)	0	NS
Convulsions	3 (13)	0	0	NS
Blood analysis				
Leukocyte count, cells × 10 ³ /μL, mean value ± SD	15.6 ± 5.8	12.7 ± 2.6	15.3 ± 3.4	NS
Differential leukocyte count, no. of patients (%)				
Granulocyte > 70%	9 (39.1)	5 (41.7)	16 (53.3)	NS
Granulocyte ≤ 70%	2 (8.7)	4 (33.3)	10 (33.3)	
Unknown	12 (52.2)	3 (25.0)	4 (13.3)	
CSF analysis				
Leukocyte count, cells/μL, median value (range)	212 (6-6200)	2000 (12-24000)	540 (12-20000)	<0.001 (A/C vs B)
Type of leukocytes, no. of patients (%)	12 (52.2)	8 (66.7)	14 (46.7)	NS
Mainly granulocytes	1 (4.4)	1 (8.3)	1 (3.3)	
Mainly lymphocytes	1 (4.4)	0 (-)	2 (6.7)	
Granulocytes and lymphocytes	9 (39.1)	3 (25.0)	13 (43.3)	
Unknown	34 (4-43)	21 (0-38)	27 (0.48)	NS
Glucose level, mg/dL, median value (range)				
CSF-to-blood glucose ratio, no. of patients (%)	10 (43.5)	3 (25.0)	3 (10.0)	NS
≥ 0.5	7 (30.4)	8 (66.7)	20 (66.7)	
< 0.5	6 (26.1)	1 (8.3)	7 (23.3)	
Unknown	248 (51-4970)	274 (65-1215)	253 (85-1400)	NS
Protein level, mg/dL, median value (range)				

Group A: Patients with EVD-related meningitis, Group B: Patients with ESD-related meningitis, Group C: Patients with postoperative non-device-related meningitis, NS: Non-significant

when the CSF culture was performed. Microorganisms responsible for meningitis are presented in Table 4.

All patients received intravenous antibiotic therapy. In addition, 3 patients (13%) in group A, 2 (16.7%)

in group B, and 1 (3.3%) in group C received intrathecal antibiotics. Median intravenous antibiotic treatment duration was 20 days (range: 5–57 days) in group A, 17 days (range: 4–60 days) in group B, and 22.5 days (range: 3–41 days) in group C. There was no significant difference in the length of therapy between the three groups.

Table 4: Microbiological findings of CSF culture

Pathogen	Group A (n=23) no. of isolates (%)	Group B (n=12) no. of isolates (%)	Group C (n=30) no. of isolates (%)
Methicillin-resistant <i>S. epidermidis</i>	9 (39.1)	4 (33.3)	4 (13.3)
Methicillin-susceptible <i>S. epidermidis</i>	2 (8.7)	0	2 (6.7)
Methicillin-resistant <i>S. aureus</i>	2 (8.7)	0	0
Methicillin-susceptible <i>S. aureus</i>	1 (4.3)	1 (8.3)	0
Coagulase-negative staphylococci	1 (4.3)	2 (16.7)	2 (6.7)
<i>E. faecalis</i>	1 (4.3)	0	1 (3.3)
<i>E. faecium</i>	0	0	1 (3.3)
Vancomycin-resistant <i>Enterococcus</i>	0	0	2 (6.7)
<i>S. agalactiae</i>	0	0	1 (3.3)
<i>E. coli</i>	1 (4.3)	2 (16.7)	1 (3.3)
<i>Acinetobacter</i> spp	1 (4.3)	0	0
<i>Enterobacter</i> spp	0	2 (16.7)	0
<i>P. aeruginosa</i>	0	0	3 (10.0)

Group A: Patients with EVD-related meningitis, Group B: Patients with ESD-related meningitis, Group C: Patients with postoperative non-device-related meningitis, NS: Non-significant

Clinical, biochemical, and microbiological course of meningitis

Description of the clinical, biochemical, and microbiological course of meningitis is shown in Table 5. Overall, 8 patients (34.8%) in group A, 3 (25.0%) in group B, and 3 (10.0%) in group C died. Among patients in group A, 1 patient (12.5%) experienced meningitis treatment failure and died because of methicillin-resistant *Staphylococcus aureus* meningitis, 6 patients (75.0%) extra-central nervous system (CNS) infections, and 1 patient (12.5%) died because of cardiovascular complications. All patients in groups B and C (100.0%) died due to severe, CNS infections [Table 6].

Removing devices (both EVD and ESD) in the first 48 hours after meningitis onset was associated with shorter time to CSF leukocyte reduction (median 5 days versus 8 days, $P = 0.05$), and shorter time to CSF bacterial clearance (median of 5 days versus 8 days, $P = 0.05$) [Table 7].

In patients with EVD and ESD-related meningitis, positioning of a second device was associated with longer median time to bacterial clearance (11.5 days versus 7.5 days, $P = 0.03$).

Table 5: Clinical characteristics, blood/CSF chemistry and CSF bacterial clearance at the end of treatment

Variable	Group A (n=23)	Group B (n=12)	Group C (n=30)	P
Afebrile patients, no. (%)	16 (69.6)	9 (75.0)	29 (96.7)	NS
Time to $T \leq 37^\circ\text{C}$, median days (range)	12 (4-37)	7 (3-22)	10 (0-47)	0.04 (A vs C)
Patients with normalized blood leukocyte count, no. (%)*	11/16 (68.8)	6/10 (60)	19/26 (73.1)	NS
Time to normalize blood leukocyte count, median days (range)	12 (1-19)	11.5 (7-37)	5 (1-25)	NS
Patients with improved CSF glucose value, no. (%)*	14/15 (93.3)	8/10 (80.0)	19/26 (73.1)	NS
Time to improve CSF glucose, median days (range)	11 (4-26)	3.5 (1-31)	9 (2-42)	NS
Patients with normalized CSF glucose value, no. (%)*	10/15 (66.7)	5/10 (50.0)	10/26 (38.5)	NS
Time to normalize CSF glucose, median days (range)	14 (6-43)	15 (2-31)	13 (2-42)	NS
Patients with improved CSF leukocyte count, no. (%)*	18/21 (85.7)	11/12 (91.7)	23/30 (76.7)	NS
Time to improve CSF leukocyte count, median days (range)	8 (1-26)	4 (1-18)	6 (2-27)	NS
Patients with normalized CSF leukocyte count, no. (%)*	10/21 (47.6)	3/12 (25.0)	8/30 (26.7)	NS
Time to normalize CSF leukocyte count, median days (range)	7 (1-43)	39 (10-41)	20.5 (9-27)	0.04 (A vs C)
Patients with CSF bacterial clearance, no. (%)*	17/18 (94.4)	11/11 (100.0)	16/17 (94.1)	NS
Time to bacterial clearance, median days (range)	6.5 (1-25)	4 (1-24)	11.5 (2-27)	NS

Group A: Patients with EVD-related meningitis, Group B: Patients with ESD-related meningitis, Group C: Patients with postoperative non-device-related meningitis, NS: Non-significant, *: Denominators indicate the number of patients for whom the variable is out of range (or the CSF culture is positive) at meningitis onset or during meningitis course

DISCUSSION

Our single-center study of 77 consecutive events of postoperative meningitis is, to our knowledge, the first study aimed to compare the clinical, biochemical, and microbiological course, as well as the outcome of device and non-device-related meningitis.

Our results show an overall post-neurosurgical meningitis rate of 4.9%, which is well within the range observed in other studies,^[3,9] but with great variability per year (0–14%). Similar to the findings of other studies,^[1,2,4,12,13] EVD-related meningitis in our population occurred within the first week (median of 6 days, range of 0–28) after EVD placement. ESD-associated meningitis occurred even earlier (median of 3 days, range of 0–20), probably due to a higher load of bacteria caused by the proximity between the drainage and the perineal area. As expected, bacteria belonging to the fecal flora were isolated more frequently in ESD patients (4 out of 12, 33.3%) compared to non-ESD patients (7 out of 46, 13.2%). The difference was not statistically

significant ($P = 0.1$) probably due to a low number effect.

Of note, the presence of a ventricular drainage influenced the time to meningitis resolution. Time to bacterial clearance and improved CSF leukocyte count were significantly shorter in patients with early device removal; moreover, implantation of a second device was associated with longer time to bacterial clearance in CSF. This observation is consistent with the knowledge that any device and related biofilm facilitates bacterial survival and hampers the effect of antibiotic treatment. These findings support attempts to remove devices as early as possible and to avoid positioning of a second CSF drainage catheter whenever possible.

Based on the study results, we updated the algorithm for the management of patients with proven or possible postoperative meningitis [Figure 1].

Our study has several limitations. Due to its partially retrospective design, diagnostic and therapeutic procedures were not systematically standardized. Furthermore, patients' subgroups were small and with limited ability to identify significant associations of one or a group of variables. However, we analyzed a large number of ESD-related meningitis, which have rarely been investigated to date.^[5,6] To our knowledge, this is the first study that takes into account the clinical, biochemical, and microbiological course of meningitis and its outcome with particular attention to the influence of CSF drainage catheters.

Table 6: Concomitant extra-CNS infections, patients' outcome and length of hospitalization

Variable	Group A (n=23)	Group B (n=12)	Group C (n=30)	P
Extra-CNS infections				
Total, no. of episodes	24	14	26	NS
Pneumonia, no. of episodes (%)	14 (58.3)	6 (42.9)	11 (42.3)	NS
Sepsis/septic shock, no. of episodes (%)	7 (29.2)	6 (42.9)	5 (19.2)	NS
Urinary tract infection, no. of episodes (%)	3 (12.5)	1 (7.1)	6 (23.1)	NS
Clostridium difficile, no. of episodes (%)	0	0	1 (3.8)	NS
Other infections, no. of episodes (%)	0	1 (7.1)	3 (11.5)	NS
Deaths, no. (%)	8 (34.8)	3 (25.0)	3 (10.0)	NS
Length of hospitalization, median days (range)	48 (30-150)	58.5 (23-231)	44 (81-91)	NS

Group A: Patients with EVD-related meningitis, Group B: patients with ESD-related meningitis, Group C: Patients with postoperative non-device-related meningitis, NS: Non-significant

CONCLUSION

In summary, early device removal was associated with shorter illness duration, whereas implantation of a second device during the course of meningitis was associated with a longer resolution time. These observations will need to be validated in a prospective study in order to better define the timing of device removal, its eventual repositioning, as well as the best antibiotic regimen.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

Table 7: Effect of the device removal and repositioning on meningitis

Variable	< 48 hours device's removal (n=25)	> 48 hours (n=22)	P	Implantation of a second device (n=25)	No second device (n=22)	P
Time to improve CSF leukocyte count, median days	5 (1-22)	8 (1-18)	0.05	8 (1-22)	6 (1-20)	ns
Time to improve CSF glucose, median days	4 (1-17)	6 (1-30)	ns	11,5 (1-30)	9 (1-17)	ns
Time to bacterial clearance, median days	5 (1-34)	8 (1-24)	0.05	11,5 (1-34)	7,5 (1-16)	0.03

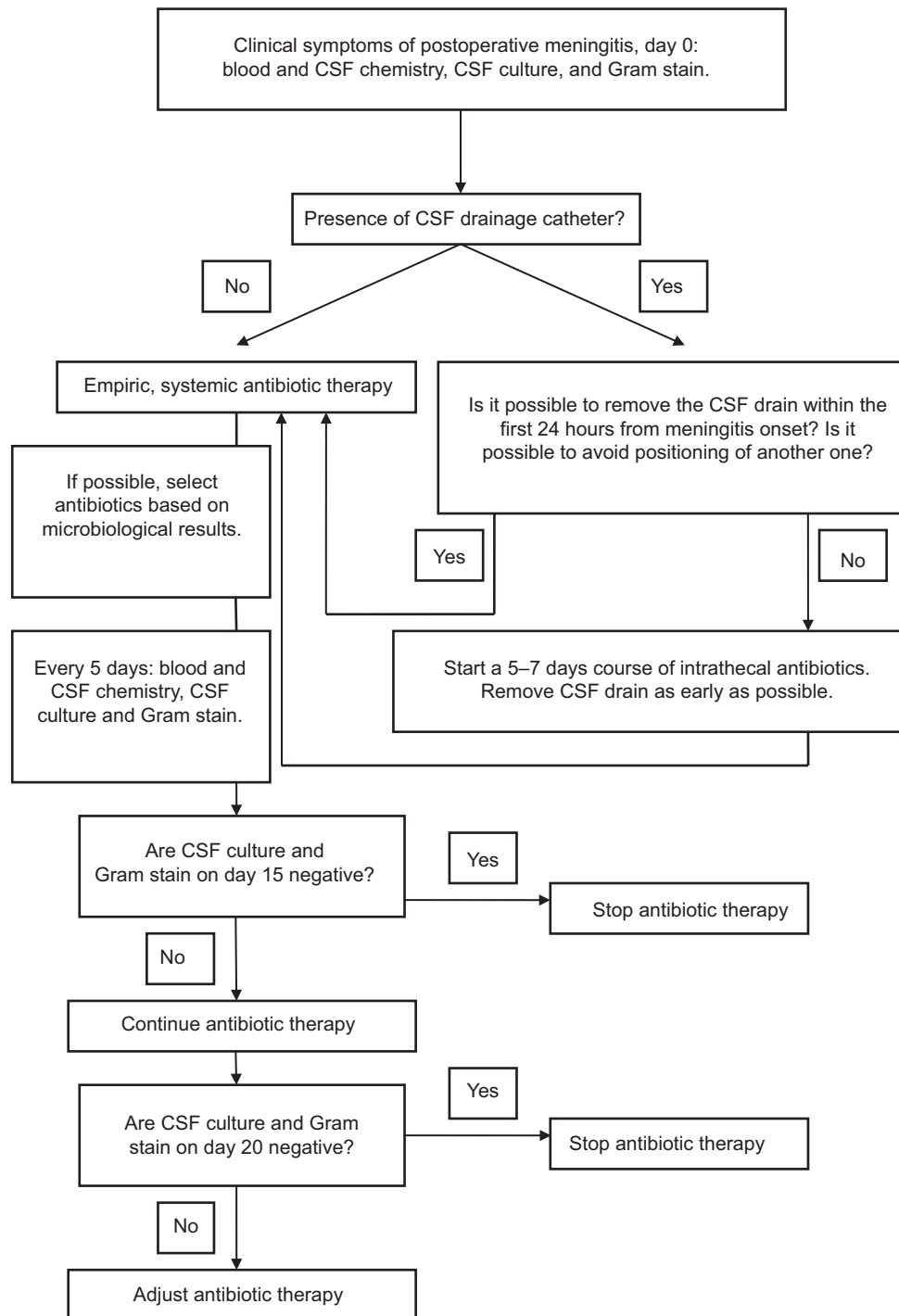


Figure 1: Diagnostic and therapeutic algorithm for suspicion of postoperative or drain-related meningitis

REFERENCES

1. Arabi Y, Memish ZA, Balkhy HH, Francis C, Ferayan A, Al Shimemeri A, et al. Ventriculostomy-associated infections: Incidence and risk factors. *AJIC* 2005;33:137-43.
2. Bogdahn U, Lau W, Hassel W, Gunreben G, Mertens HG, Brawanski A. Continuous-pressure controlled, external ventricular drainage for treatment of acute hydrocephalus – Evaluation of risk factors. *Neurosurgery* 1992;31:898-904.
3. Citerio G, Signorini L, Bronco A, Vargiolu A, Rota M, Latronico N; Infezioni Liquorali Catetere Correlate Study Investigators. External Ventricular and Lumbar Drain Device Infections in ICU Patients: A Prospective Multicenter Italian Study. *Crit Care Med* 2015;43:1630-7.
4. Conen A, Walti LN, Merlo A, Fluckiger U, Battegay M, Trampuz A. Characteristics and treatment outcome of cerebrospinal fluid shunt-associated infections in adults: A retrospective analysis over an 11-year period. *Clin Infect Dis* 2008;47:73-82.
5. Coplin WM, Avellino AM, Kim DK, Winn HR, Grady MS. Bacterial meningitis associated with lumbar drains: A retrospective cohort study. *J Neurol Neurosurg Psychiatry* 1996;67:468-73.
6. Governale LS, Fein N, Logsdon J, Black PM. Techniques and complications of

- external lumbar drainage for normal pressure hydrocephalus. *Neurosurgery* 2008;63(Suppl 2):379-84.
7. Holloway KL, Barnes T, Choi S, Bullock R, Marshall LF, Eisenberg HM, et al. Ventriculostomy infections: The effect of monitoring duration and catheter exchange in 584 patients. *J Neurosurg* 1996;85:419-24.
 8. Korinek AM, Reina M, Boch AL, Rivera AO, De Bels D, Puybasset L. Prevention of external ventricular drain-related ventriculitis. *Acta Neurochir* 2005;147:39-46.
 9. Lozier AP, Sciacca RR, Romagnoli MF, Sander Connolly E. Ventriculostomy-related infections: A critical review of the literature. *Neurosurgery* 2002;51:170-82.
 10. Lyke KE, Obasanjo OO, Williams MA, O'Brien M, Chotani R, Perl TM. Ventriculitis complicating use of intraventricular catheters in adult neurosurgical patients. *Clin Infect Dis* 2001;33:2028-33.
 11. Mayhall CG, Archer NH, Lamb VA, Spadora AC, Baggett JW, Ward JD, et al. Ventriculostomy-related infections. A prospective epidemiologic study. *N Engl J Med* 1984;310:553-9.
 12. Park P, Garton HJ, Kocan MJ, Thompson BG. Risk of infection with prolonged ventricular catheterization. *Neurosurgery* 2004;55:594-601.
 13. Pfisterer W, Muehlbauer M, Czech T, Reinprecht A. Early diagnosis of external ventricular drainage infection: Results of a prospective study. *J Neurol Neurosurg Psychiatry* 2003;74:929-32.
 14. van de Beek D, Drake JM, Tunkel AR. Nosocomial bacterial meningitis. *N Engl J Med* 2010;362:146-54.