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Article

Incidence of Meningitis in Patients Undergoing Decompressive Craniectomy at Shaheed Mohtarma Benazir Bhutto Institute of Trauma Center, Karachi

Asjad Qureshi[1], Zulqarnain[1], Muhammad Mohsin Jummani[1], Talha Bhatti[1], Shuja Shaukat[1], Shabih Ayeshah[2], Abdul Basit Ansari[1], Muhammad Muizz Uddin[1]

1 Shaheed Mohtarma Benazir Bhutto Institute of Trauma, Dr Ruth KM Pfau Civil Hospital Karachi & Dow University of Health Sciences (DUHS), Karachi, Pakistan
2 Chiniot General Hospital, Karachi, Pakistan

Correspondence
asjad.cancer.qureshi034@gmail.com

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ABSTRACT

Background: Meningitis remains a significant postoperative complication in neurosurgical patients, particularly following decompressive craniectomy (DC), which is often performed to manage elevated intracranial pressure due to trauma, stroke, or mass lesions. Despite the life-saving potential of DC, limited regional data exist regarding the incidence and predictors of postoperative meningitis in such patients. **Objective**: To determine the incidence of postoperative meningitis and its association with cerebrospinal fluid (CSF) abnormalities in patients undergoing decompressive craniectomy at the Shaheed Mohtarma Benazir Bhutto Institute of Trauma Center, Karachi. **Methods**: This cross-sectional observational study included 150 adult patients (n = 150) who underwent DC for various neurosurgical indications. Patients with pre-existing meningitis or lost to follow-up were excluded. Data were collected on demographic variables, comorbidities, preoperative status, CSF analysis, and clinical signs of meningitis. Ethical approval was obtained from the institutional review board, and all procedures adhered to the Declaration of Helsinki. Statistical analysis was performed using SPSS version 25, with a significance level set at $p < 0.05$. **Results**: The incidence of clinical meningitis was 10% (15/150). Abnormal CSF findings were significantly associated with meningitis ($p = 0.02$), with 42.9% of patients with abnormal CSF developing infection compared to 8.4% with normal CSF. No significant associations were observed with surgical indication, preoperative condition, or comorbidities. **Conclusion**: Postoperative meningitis is a clinically relevant complication in DC patients, with CSF abnormalities serving as a significant predictive marker. These findings emphasize the importance of early CSF monitoring and targeted antibiotic strategies to improve neurosurgical outcomes.

Keywords: Meningitis, Decompressive Craniectomy, Cerebrospinal Fluid, Neurosurgery, Postoperative Comp

INTRODUCTION

Decompressive craniectomy (DC) is a neurosurgical procedure that alleviates elevated intracranial pressure (ICP) resulting from conditions such as traumatic brain injury (TBI), stroke, tumors, or other causes of cerebral edema (1). By removing a portion of the skull, this intervention allows for brain expansion and reduces the risk of brain herniation and secondary neurological injury (2). Although DC is often life-saving, it is not without complications. Among the most concerning is postoperative meningitis—a serious inflammation of the meninges that can significantly worsen neurological outcomes and increase patient mortality (3). Meningitis in postoperative settings is typically associated with breaches in the dura mater, prolonged intensive care stays, cerebrospinal fluid (CSF) leaks, and the use of invasive monitoring devices such as external ventricular drains (EVDs) (8, 9). These risks necessitate heightened vigilance and rigorous infection control practices.

The body of literature evaluating DC outcomes has grown substantially over recent years, especially following landmark studies such as the RESCUE ICP trial. This trial demonstrated that while DC reduced mortality in patients with refractory intracranial hypertension, it was associated with increased rates of severe disability and vegetative states, raising complex ethical and management concerns (4). Despite these findings, DC continues to be employed as an essential intervention in both high- and low-resource trauma settings. Several studies have since evaluated its efficacy in various clinical scenarios, consistently highlighting the need to balance survival benefits against the risk of long-term disability and complications (5, 6). However, specific data on the incidence and risk factors of postoperative meningitis among DC patients remain sparse, especially in low- and middle-income countries where resource limitations may compound the risks.

Infection control in neurosurgical patients, particularly those undergoing DC, is complicated by factors such as prolonged ICU admissions, immunosuppressive comorbidities, and limited access to preventive infrastructure (7). Research indicates that parameters such as midline shift, flap size, and the use of intracranial pressure monitors are critical in predicting both mortality and postoperative infections (7, 13). Moreover, pre-existing comorbidities like diabetes mellitus have been independently linked to increased susceptibility to meningitis, possibly due to impaired immune function and delayed wound healing (12). The presence of abnormal CSF findings has also emerged as a significant marker of underlying meningitic processes, often preceding the development of clinical symptoms. Nevertheless, there is a dearth of focused investigations assessing these associations in post-DC populations, particularly in the South Asian context.

Despite the availability of generalized infection data from neurosurgical units, few studies have quantified the incidence of meningitis specifically in patients post-DC, and even fewer have explored predictors such as preoperative condition, duration of ICU stay, or CSF abnormalities. Additionally, regional studies evaluating the impact of microbial flora, hospital protocols, and surgical techniques on postoperative meningitis outcomes are limited. The lack of such data impedes the development of tailored clinical guidelines and prophylactic measures in local neurosurgical centers. Given the life-threatening nature of meningitis and its implications on neurological recovery, understanding its prevalence and associated factors in post-DC patients is critical.

The current study, therefore, aims to determine the incidence of meningitis in patients undergoing decompressive craniectomy at the Shaheed Mohtarma Benazir Bhutto Institute of Trauma Center in Karachi. It further seeks to evaluate the potential association of meningitis with clinical and demographic variables, including CSF abnormalities, preoperative status, and comorbidities. By identifying the burden and predictors of postoperative meningitis in this patient population, the study intends to inform early diagnostic strategies and improve perioperative care protocols in high-risk neurosurgical settings.

MATERIAL AND METHODS

This cross-sectional observational study was conducted at the Shaheed Mohtarma Benazir Bhutto Institute of Trauma Centre, Karachi, Pakistan, to determine the incidence of meningitis in adult patients undergoing decompressive craniectomy. A total of 150 patients, aged 18 years and above, from both genders were recruited through non-probability consecutive sampling. Inclusion criteria consisted of patients who underwent decompressive craniectomy for trauma, stroke, tumor, or other neurologic emergencies during their hospital stay. Patients were excluded if they presented with active infections, particularly meningitis, at the time of surgery, were being treated for non-trauma-related conditions, or if they defaulted from follow-up within one month postoperatively. All participants provided written informed consent prior to inclusion in the study, and patient data were handled confidentially in accordance with the Declaration of Helsinki.

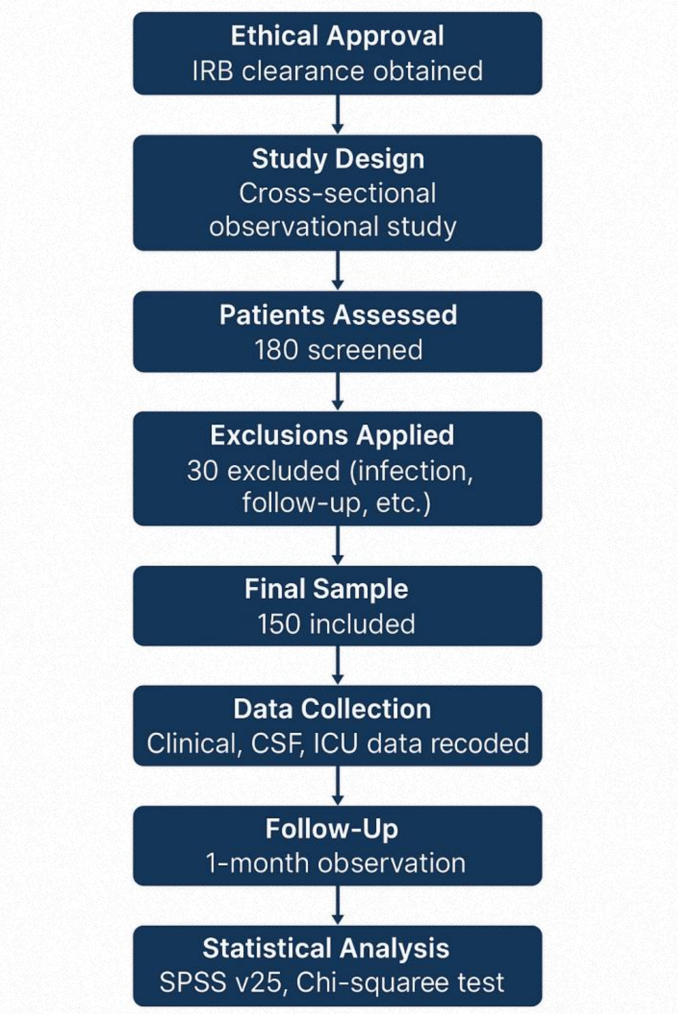

Figure 1 Flowchart illustrating the study methodology and outcomes in patients undergoing decompressive craniectomy.

Participants were assessed clinically at the time of admission, during surgery, and throughout their hospital stay, including a follow-up period of one month post-surgery. The primary outcome was the development of clinical meningitis, which was defined based on clinical signs and symptoms including fever, neck stiffness, altered mental status, and supported by CSF analysis where available. Secondary outcomes included the identification of any preoperative factors or CSF abnormalities associated with meningitis incidence. A structured data collection form was used to gather demographic details (age, gender, and relevant medical history such as diabetes and hypertension), preoperative clinical status, surgical indication, length of hospital and ICU stay, and laboratory CSF study results. CSF analysis was categorized as normal or abnormal based on institutional laboratory criteria. All data were collected prospectively during hospitalization and follow-up visits up to one month after the surgical procedure.

The data were entered and analyzed using the Statistical Package for Social Sciences (SPSS) version 25. Categorical variables such as gender, comorbidities, indication for surgery, and CSF findings

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were summarized using frequencies and percentages. Quantitative variables like age and duration of hospital or ICU stay were presented as means and standard deviations. Chi-square tests were applied to evaluate associations between categorical variables and the development of meningitis. A p-value less than 0.05 was considered statistically significant for all analyses.

RESULTS

A total of 150 patients undergoing decompressive craniectomy were enrolled in the study. The mean age of the cohort was 49.5 ± 19.07 years, with a predominance of male patients (n = 82, 55%) compared to females (n = 68, 45%). Regarding pre-existing comorbidities, 41 patients (27%) had diabetes mellitus, 31 (21%) had hypertension, and 14 (9%) were affected by both conditions. Additionally, 64 patients (43%) reported other comorbid medical conditions.

The indications for decompressive craniectomy varied: stroke (n = 41, 27%) and trauma (n = 40, 26%) were the most common, followed by other causes (n = 40, 26%) and tumors (n = 29, 19%). At the time of surgery, 58 patients (39%) were categorized as critically ill, while the remaining 92 (61%) were clinically stable. A total of 13 patients (8%) had preoperative infections not related to meningitis. The average duration of hospital stay was 15.38 ± 7.3 days, with a mean ICU stay of 7.1 ± 4.1 days.

Cerebrospinal fluid (CSF) analysis was performed in all patients. Abnormal CSF findings were identified in 7 patients (4%), whereas 143 patients (96%) had normal CSF results. Clinical meningitis was diagnosed in 15 patients, yielding an overall incidence rate of 10%. Among those with abnormal CSF, 3 (42.9%) developed meningitis, while 12 cases (8.4%) of meningitis occurred in patients with normal CSF. This difference was statistically significant (p = 0.02), indicating a strong association between CSF abnormalities and the development of postoperative meningitis.

Stratification of meningitis cases by surgical indication revealed no statistically significant association (p = 0.087), although meningitis was observed across all categories: trauma (n = 4), tumor (n = 3), stroke (n = 2), and other causes (n = 3). Similarly, no significant association was found between preoperative condition and postoperative meningitis (p = 0.064), with meningitis developing in 9 of 58 critically ill patients and 6 of 92 stable patients. Preoperative infection also did not demonstrate a significant correlation with meningitis occurrence (p = 0.621), as only 1 of the 13 patients with preoperative infection developed meningitis.

Table 1. Demographic and Clinical Characteristics of Patients Undergoing Decompressive Craniectomy (N = 150)

Variable	Mean ± SD / Frequency (%)
Age (years)	49.5 ± 19.07
Gender	
- Male	82 (55%)
- Female	68 (45%)
Medical History	
- Diabetes	41 (27%)
- Hypertension	31 (21%)
- Both	14 (9%)
- Other Comorbidities	64 (43%)

Table 2. Surgical and Postoperative Variables

Variable	Mean ± SD / Frequency (%)
Reason for Craniectomy	
- Tumor	29 (19%)
- Trauma	40 (26%)
- Stroke	41 (27%)
- Other Causes	40 (26%)
Preoperative Condition	
- Critical	58 (39%)
- Stable	92 (61%)
Preoperative Infection	13 (8%)
Hospital Stay (days)	15.38 ± 7.3
ICU Stay (days)	7.1 ± 4.1
CSF Findings	
- Abnormal	7 (4%)
- Normal	143 (96%)
Clinical Meningitis	15 (10%)

The association between CSF findings and meningitis, however, remained statistically significant, with an odds ratio suggesting a clinically relevant increase in risk among patients with abnormal CSF parameters. No interaction effects or post hoc comparisons were necessary, as group sizes and p-values did not justify further subgroup analyses.

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Table 3. Stratification of Clinical Meningitis by Preoperative and Postoperative Variables

Variable	Meningitis (n = 15)	No Meningitis (n = 135)	p-value
Reason for Surgery			0.087
- Tumor	3	26	
- Trauma	4	36	
- Stroke	2	39	
- Other	3	37	
Pre-op Condition			0.064
- Critical	9	49	
- Stable	6	86	
Pre-op Infection			0.621
- Yes	1	12	
- No	14	123	
CSF Findings			0.02
- Abnormal	3	4	
- Normal	12	131	

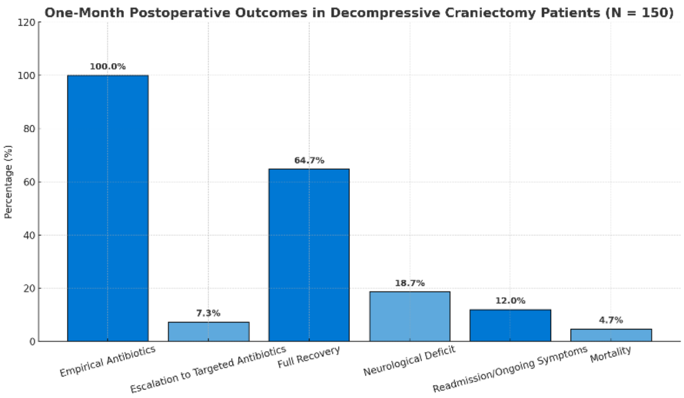

Figure 2 One Month Postoperative Outcomes

These findings underscore the clinical importance of CSF analysis in the postoperative period following decompressive craniectomy. While other variables such as indication for surgery, preoperative status, and prior infections did not show statistically significant associations, the presence of abnormal CSF findings markedly increased the likelihood of developing clinical meningitis, highlighting a potential area for early diagnostic vigilance and targeted prophylactic intervention.

DISCUSSION

In this cross-sectional analysis of 150 patients undergoing decompressive craniectomy (DC), the incidence of postoperative meningitis was identified at 10%, aligning with previously reported rates of nosocomial central nervous system infections in neurosurgical populations, which typically range from 0.5% to 8% (11). This relatively high rate in the present cohort may be attributable to local epidemiological, procedural, or healthcare system-specific factors, and emphasizes the persistent clinical challenge posed by meningitis following craniectomy. Importantly, the study demonstrated a statistically significant association between cerebrospinal fluid (CSF) abnormalities and subsequent development of meningitis (p = 0.02), reinforcing CSF analysis as a critical diagnostic and surveillance tool in the postoperative period.

The demographic profile of the study population showed a mean age of 49.5 years with a slight male predominance, consistent with the demographic distribution observed in prior studies evaluating outcomes of DC in traumatic and vascular neurological emergencies (1, 5). Comorbidities such as diabetes mellitus and hypertension were common, present in 27% and 21% of patients respectively. Notably, diabetes mellitus has been independently associated with increased susceptibility to infections, including meningitis, due to compromised immune responses and poor wound healing. Asori et al. (12) previously demonstrated an odds ratio of 6.27 for meningitis in diabetic patients, supporting the biological plausibility that systemic metabolic dysfunction may influence central nervous system vulnerability. However, despite a sizable number of diabetic patients in this cohort, no statistically significant relationship was found between diabetes or other preoperative conditions and the development of meningitis, possibly due to sample size limitations or confounding variables.

Surgical indications varied, with stroke (27%), trauma (26%), and tumors (19%) being the most common. These proportions reflect the broad application of DC in neurosurgical emergencies, and findings indicate that the etiology of the underlying condition did not significantly alter the risk of postoperative meningitis (p = 0.087). This finding is consistent with the conclusions of Solomou et al. (4), who noted that although the indication for DC determines the urgency and surgical approach, it may not significantly influence infectious outcomes if aseptic protocols are followed. Nonetheless, patients who were in critical preoperative condition and those who had pre-existing infections exhibited a trend toward higher meningitis incidence, although statistical significance was not achieved. This suggests the possibility of clinical relevance in larger or more stratified populations, warranting further investigation. One notable observation was the average time to onset of meningitis, which was 6.3 days postoperatively among affected patients. This timeline is in agreement with literature documenting postoperative central nervous system infections, where early onset meningitis typically occurs within the first week, often associated with surgical contamination or early CSF leakage (8). Prolonged ICU stays, as observed in this cohort (mean 7.1 ± 4.1 days), can further exacerbate infection risk, particularly in settings where invasive devices such as external ventricular drains (EVDs) are used. Although data regarding EVD use were not available in this study, previous multicenter studies have shown that each additional day of intracranial pressure monitoring increases the risk of infection by 24% (13), highlighting the need for optimized device protocols.

Microbiological confirmation of pathogens was not part of this study's scope, representing a key limitation. However, previous investigations in similar contexts consistently report Acinetobacter baumannii and Klebsiella pneumoniae as predominant causative organisms in postoperative meningitis (14, 15). These multidrug-resistant pathogens necessitate early empirical antibiotic strategies, with prompt escalation to targeted therapies guided by CSF profiles. In this study, empirical antibiotic therapy was universally initiated, and approximately 7.3% of patients required escalation, underlining the importance of robust microbiological surveillance in neurosurgical ICUs.

While the study provides valuable insight into infection rates and predictors following DC, certain limitations must be acknowledged. The single-center design and relatively modest sample size limit generalizability, particularly across diverse healthcare settings with variable surgical expertise and infection control protocols. The exclusion of microbiological data and long-term functional outcomes beyond one month restricts the depth of clinical insight. Furthermore, the observational design precludes causal inferences, and the reliance on clinical diagnosis of meningitis, though pragmatic, introduces potential for diagnostic variability.

Despite these limitations, the study's strengths include prospective data collection, standardized postoperative monitoring, and a focus on a clinically significant yet underreported complication in neurosurgical practice. Future research should aim to incorporate multicenter datasets with larger sample sizes, pathogen identification, and longitudinal follow-up. Incorporating variables such as type and duration of invasive monitoring, detailed immunological profiles, and neurocognitive outcomes would further refine our understanding of infection risk stratification. Moreover, the development of predictive models integrating clinical, biochemical, and procedural factors could aid in early identification of high-risk patients and guide prophylactic interventions.

In conclusion, this study reinforces the clinical significance of postoperative meningitis in patients undergoing decompressive craniectomy, particularly in relation to CSF abnormalities. It emphasizes the need for vigilant monitoring, early diagnostic testing, and appropriate antibiotic stewardship. As DC continues to serve as a life-saving intervention in neurocritical care, parallel efforts to mitigate infectious complications are essential to optimize patient outcomes.

CONCLUSION

This study identified a 10% incidence of postoperative meningitis among patients undergoing decompressive craniectomy at the Shaheed Mohtarma Benazir Bhutto Institute of Trauma Center, Karachi, with a significant association observed between abnormal cerebrospinal fluid findings and meningitis development. These results underscore the importance of early CSF analysis as a predictive marker for infection, emphasizing the need for heightened clinical vigilance and infection control measures in neurosurgical care. The findings have direct implications for improving postoperative surveillance protocols and antibiotic stewardship in trauma and neurocritical settings. Clinically, this evidence supports the integration of routine CSF monitoring in postoperative management, while future research should explore pathogen-specific risks, long-term neurological outcomes, and the development of predictive models to guide individualized prophylactic strategies.

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