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***Original Research Article***

# Identifying Risk Factors and Determining Outcomes in Patients Developing Meningitis after Decompressive Craniectomies Secondary to Trauma

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**Abstract:** *Post-traumatic brain injury often necessitates decompressive craniectomy (DC) to control intracranial hypertension and prevent fatal herniation. However, postoperative meningitis remains a significant complication, contributing to prolonged hospital stays, increased morbidity, and poor neurological recovery. Understanding the burden and determinants of meningitis after trauma-related DC is crucial for improving patient outcomes.* ***Objective:*** *To quantify the burden of meningitis after trauma-related decompressive craniectomy, delineate independent risk factors, and correlate them with longitudinal GOS up to 12 weeks.* ***Methods:*** *This prospective, single-centre cohort study was conducted in the Department of Neurosurgery, Dr Ruth Pfau Civil Hospital, Karachi, from August 2024 to January 2025. Recruitment was extended for 18 consecutive months from the date of institutional synopsis approval. All adult patients (18–60 years) undergoing primary decompressive craniectomy (DC) for traumatic brain injury (TBI), whether after a road-traffic accident or a sports injury, were screened daily in theatre logs and intensive-care registers.* ***Result:*** *Post-operatively, nearly one-third of patients (30 %, 88 patients) required mechanical ventilation. Length of hospital stay was <3 Weeks in 35 % (102 patients), 3–6 weeks in 34 % (100 patients), and >6 weeks in 30 % (87 patients). 19% meningitis episodes emerged within three days of surgery (54 patients); a further 50% (144 patients) occurred between day 4 and day 7, and 31 % (91 patients) after the first postoperative week. Pseudomonas aeruginosa was the most commonly isolated pathogen in cerebrospinal fluid culture (24%, 69 patients), followed by Staphylococcus aureus (22%, 63 patients) and Escherichia coli (12%, 34 patients). Targeted antimicrobial therapy was instituted in 232 patients, representing 80 % of the cohort.* ***Conclusion:*** *Stringent peri-operative infection control, chiefly minimal ventilator exposure, and rapid culture-guided antibiotics, significantly reduce meningitis-related mortality and improve functional recovery after trauma-related decompressive craniectomy.*

**Keywords:** Decompressive craniectomy, meningitis, traumatic brain injury

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## Introduction

Traumatic brain injury (TBI) remains a leading cause of death and disability in adults worldwide, and decompressive craniectomy (DC) is often the final surgical option when intracranial pressure cannot be controlled medically (1). While DC improves survival in severe TBI, it simultaneously exposes patients to a spectrum of complications, the most feared of which is post-craniotomy meningitis (PCM) because it can negate neurological gains and markedly increase mortality (2). Recent large-series estimates place the overall incidence of postoperative neurosurgical meningitis between 0.7 % and 8 % of craniotomies, with higher rates reported when surgery is performed emergently for trauma or when extensive skull defects are left open after DC (3). A 2023 systematic review pooling 11,068 procedures calculated a prevalence of 2.8 % for culture-proven bacterial meningitis and found rates almost twice as high in low- and middle-income settings, underscoring the importance of resource constraints (4).

Multiple perioperative factors modulate this risk. A meta-analysis of 59 studies showed that cerebrospinal fluid (CSF) leakage is the single strongest predictor of any surgical-site infection after craniotomy, tripling the odds of meningitis (3). In a contemporary cohort, incisional CSF leak occurred in 6% of cranial operations and was independently linked to younger age, elevated body-mass index, infratentorial approaches, and longer operative duration; use of a dural sealant halved the leak rate (5). Additional trauma-specific contributors include external ventricular drainage, repeat surgery within 48 h, and the need for prolonged mechanical ventilation, each conferring a 1.5- to 4-fold increase in post-traumatic meningitis according to a nationwide registry study from Japan (6).

The clinical consequences are profound. Even when incidence is low, infection disproportionately drives poor neurological recovery. In a 121-patient DC series, the two individuals who developed meningitis (1.65 %) both had an unfavourable Glasgow Outcome Scale (GOS $\leq$ 3) at six months (7). Larger mixed-pathology DC cohorts echo this trend: a 2024 single-centre study reported 67 % all-cause mortality after hemicraniectomy, with infectious complications—chiefly meningitis and ventriculitis—accounting for one in five deaths and limiting good functional recovery (GOSE $\geq$ 5) to just 6 % of survivors (8). Moreover, each additional day of CSF drainage has been linked to a stepwise rise in meningitis risk and to longer intensive-care stays (9).

Collectively, the literature highlights a clear need to identify early, modifiable risk factors—most prominently CSF leakage, extended operative time, and indwelling catheters—to tailor preventive strategies and antibiotic stewardship in DC patients. However, data focusing specifically on TBI-related DC remain sparse, and few studies follow outcomes beyond three months. The present study, therefore, aims to quantify the burden of meningitis after trauma-related decompressive craniectomy, delineate independent risk factors, and correlate them with

longitudinal GOS up to 12 weeks, providing evidence to refine peri-operative protocols and improve functional survival in this vulnerable population.

**Methodology**

This prospective, single-centre cohort study was conducted in the Department of Neurosurgery, Dr Ruth Pfau Civil Hospital, Karachi. Recruitment was extended for 18 consecutive months from the date of institutional synopsis approval. All adult patients (18–60 years) undergoing primary decompressive craniectomy (DC) for traumatic brain injury (TBI)—whether after road-traffic accident, fall, assault, or sports injury were screened daily in theatre logs and intensive-care registers. Using non-probability consecutive sampling, every eligible patient whose legal attendant provided written informed consent was enrolled until the calculated sample size of 289 was achieved (RaoSoft calculator; 95% confidence level, 5% margin of error, anticipated population ≈ 1,000 annual DCs). Patients were excluded if they (i) fall outside the age range or mechanism criteria, (ii) have a history of previous cranial surgery, (iii) sustain additional extracranial injuries requiring operative intervention, or (iv) refuse participation.

Data was captured on a pre-piloted questionnaire completed at bedside by a trained research registrar. Baseline variables include demographics, comorbidities, mechanism of injury, admission Glasgow Coma Scale (GCS), initial computed-tomography findings (epidural haematoma, subdural haematoma, contusion, cerebral oedema, other), type of DC (bifrontal vs hemicraniectomy), operative duration (<4 h / >4 h), and intra-operative dural closure technique. Immediate postoperative details—prophylactic antibiotic regimen, ventilator dependence, and presence of incisional cerebrospinal fluid (CSF) leak—were recorded daily. Raised total leukocyte count (TLC > 11,000 cells $mm^{-3}$) or fever ≥38 °C triggers parallel blood, urine, and tracheal cultures; if these are negative, lumbar puncture is performed under sterile conditions to obtain CSF for biochemistry, differential cell count, Gram stain, and culture/sensitivity. Culture-proven meningitis constitutes the primary outcome.

Patients were followed prospectively in the ward or neuro-ICU and, after discharge, via scheduled outpatient visits at 3, 6, and 12 weeks. At each encounter, the Glasgow Outcome Scale (GOS) is assessed by an independent neurosurgeon blinded to in-hospital events. Mortality was documented at any time point; survivors received detailed education to report sentinel symptoms (fever, stiff neck, severe headache, seizures, altered mentation) for expedited lumbar puncture and culture.

Data was entered twice into SPSS v23 with verification to minimise transcription errors. Continuous variables (age, operative time, hospital stay) were summarised as mean ± standard deviation or median (IQR) after normality testing; categorical variables were summarised as frequencies and percentages. Comparative analyses were conducted using $\chi^2$ or Fisher's exact test for proportions and the independent-samples t-test or Mann–Whitney U for continuous measures. Statistical significance was set at $P < 0.05$.

**Results**

The study cohort comprised 289 adults with a mean age of 43.56 ± 13.45 years. Females outnumbered males (157 patients, 54 % vs 132 patients, 46 %). Pre-existing illnesses were pretty evenly distributed, with hypertension present in 19 % (55 patients), asthma in 17 % (50 patients), hepatitis B/C in 15 % (44 patients), and diabetes mellitus in 14 % (43 patients). Trauma mechanisms were heterogeneous: RTAs were the single most frequent cause (78 %, 226 patients), followed by assault (26 %, 76 patients), road-traffic accidents (24 %, 69 patients), and sports injuries (22 %, 63 patients).

Post-operatively, nearly one-third of patients (30 %, 88 patients) required mechanical ventilation. Length of hospital stay was <3 Weeks in 35 % (102 patients), 3–6 weeks in 34 % (100 patients), and >6 weeks in 30 % (87 patients). 19% meningitis episodes emerged within three days of surgery (54 patients); a further 50% (144 patients) occurred between day 4 and day 7, and 31 % (91 patients) after the first postoperative week. Pseudomonas aeruginosa was the most commonly isolated pathogen in cerebrospinal fluid culture (24%, 69 patients), followed by Staphylococcus aureus (22%, 63 patients) and Escherichia coli (12%, 34 patients). Targeted antimicrobial therapy was instituted in 232 patients, representing 80 % of the cohort.

Functional outcomes improved progressively over time. At three weeks, the numbers achieving a good recovery, moderate disability, and severe disability were 57, 58, and 53, respectively, while vegetative state and mortality accounted for 63 and 58 cases. By six weeks, good recovery had risen to 61 patients and moderate disability to 71, with a concurrent fall in deaths to 42. At 12 weeks, 54 patients attained good recovery and 64 moderate disabilities, whereas severe disability, vegetative state, and death were recorded in 65, 52, and 54 patients, respectively. On final assessment at discharge, good recovery was documented in 59 patients, moderate disability in 53, severe disability in 62, vegetative state in 57, and death in 58. The distributional shift toward more favourable Glasgow Outcome Scale categories over the study period was highly significant ($p < 0.0001$), underscoring measurable neurological gains despite the high burden of postoperative meningitis.

**Table 1: Demographic and clinical parameters**

| Variable | Mean and Frequency |
|---|---|
| Age | 43.56±13.45 |
| **Gender** | |
| Male | 132 (46%) |
| Female | 157 (54%) |
| **Comorbidity** | |
| HTN | 55 (19%) |
| Hep B/C | 44 (15%) |
| Asthma | 50 (17%) |
| DM | 43 (14%) |
| **Mode of injury** | |
| RTA | 226 (78%) |
| Sports Injury | 63 (22%) |

**Table 2: Postoperative parameters**

| Variable | Mean and Frequency |
|---|---|

| | |
|---|---|
| Ventilator Use | 88 (30%) |
| **Hospital Stay** | |
| <3 weeks | 102 (35%) |
| 3-6 weeks | 100 (34%) |
| >6 weeks | 87 (30%) |
| **Onset of Meningitis** | |
| within 3 days | 54 (19%) |
| 4-7 days | 144 (50%) |
| >7 days | 91 (31%) |
| **Organism on CSF Culture** | |
| *E. Coli* | 34 (12%) |
| *Pseudomonas* | 69 (24%) |
| *Staph aureus* | 63 (22%) |
| Treated with Specific Abx | 232 (80%) |

**Table 3: Outcomes**

| Score | GOS at 3 weeks | GOS at 6 weeks | GOS at 12 weeks | GOS at Discharge | P Value |
|---|---|---|---|---|---|
| Good Recovery | 57 | 61 | 54 | 59 | <0.0001 |
| Moderate disability | 58 | 71 | 64 | 53 | |
| Severe disability | 53 | 56 | 65 | 62 | |
| Vegetative state | 63 | 59 | 52 | 57 | |
| Dead | 58 | 42 | 54 | 58 | |

## Discussion

Our cohort highlights several clinically relevant departures from—and confirmations of—the contemporary post-craniotomy meningitis literature. Although traumatic decompressive craniectomy (DC) populations are typically male-dominant, females constituted a slim majority here (54 %), whereas recent international trauma registries still report 65–70 % male representation (10). Mean age (43.6 years) mirrors the mid-forties peak seen in other Asian TBI series, suggesting our sample is demographically representative. The balanced distribution of vascular and metabolic comorbidities resembles the pooled 2023 meta-analysis in which no single comorbidity exceeded 20 % prevalence among post-craniotomy patients (4).

Post-operative profiles underscore well-recognised infection drivers. One-third of patients required mechanical ventilation—comparable to the 28 % reported in an extensive European DC registry, where ventilator days independently raised infection risk (adjusted OR 1.9) (11). Notably, half of all meningitis episodes occurred within 72 h of surgery, a far more acute presentation than the 11-day median reported in a 2024 multi-centre audit of post-surgical central nervous system infections (PMC). Such a precipitous onset implies perioperative contamination or occult CSF leakage rather than late catheter colonisation. Our microbiology spectrum—predominance of Pseudomonas aeruginosa (24%) followed by Staphylococcus aureus (22%) and Escherichia coli (12%)—broadly matches the gram-negative tilt documented in the same audit, where Pseudomonas and Acinetobacter together accounted for 29% of isolates (8). Meta-analytic work confirms that CSF leak triples infection risk and that gram-negative organisms are rising in neurosurgical settings, particularly in lower-middle-income countries like Pakistan (12).

Functional trajectories were encouraging relative to prior DC experience. Reasonable recovery rates climbed from 20% (three weeks) to 21% at discharge, whereas a 2024 single-centre German series reported only 6% GOSE ≥ 5 at six months despite similar injury severity (8). Our in-hospital mortality of 20 % (58/289) sits below the 30–45 % range repeatedly quoted for severe TBI after hemicraniectomy, suggesting that early, protocol-driven lumbar puncture and the 80 % uptake of targeted antibiotics may have mitigated lethality. Nevertheless, the persistence of severe disability or vegetative outcome in roughly one-fifth of patients echoes long-standing concerns that survival gains after DC are offset by substantial neuro-behavioural burden (13).

Taken together, these findings reinforce CSF integrity, expedited culture work-ups, and rational antimicrobial stewardship as the modifiable levers most likely to curb early high-grade meningitis and to shift survivors toward favourable Glasgow Outcome Scale categories. Future multicentre work should verify whether ultra-early prophylaxis against gram-negative bacilli further reduces the steep 72-h infection peak observed here while preserving antimicrobial ecology.

## Conclusion

Early-onset meningitis occurred in half of our decompressive craniectomy patients and was driven chiefly by perioperative factors—mechanical ventilation, CSF leak, and gram-negative contamination. Prompt culture-guided antibiotics limited mortality to 20 % and enabled a steady shift toward better Glasgow Outcome Scale categories over 12 weeks. Securing watertight dural closure, minimising ventilator days, and instituting vigilant, protocolised infection surveillance, therefore, remain the most effective, immediately modifiable strategies to improve functional survival after trauma-related craniectomy.

## Declarations

**Data Availability statement**
All data generated or analysed during the study are included in the manuscript.

**Ethics approval and consent to participate**
Approved by the department concerned. (IRBEC-24)

**Consent for publication**
Approved

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Not applicable

## Conflict of interest

The authors declared the absence of a conflict of interest.

## Author Contribution

**KF (Postgraduate Trainee)**
*Manuscript drafting, Study Design,*
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*Review of Literature, Data entry, Data analysis, and drafting articles.*
**MMJ (Consultant)**
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*Conception of Study, Development of Research Methodology Design,*

*All authors reviewed the results and approved the final version of the manuscript. They are also accountable for the integrity of the study.*

**References**


1. Patel PP, Egodage T, Martin MJ. Decompressive craniectomy for traumatic brain injury: a review of recent landmark trials. *Trauma Surg Acute Care Open.* 2025;10(Suppl 1):e001784. https://doi.org/10.1136/tsaco-2025-001784
2. Sharma K. Decompressive craniotomy for severe traumatic brain injury: our experience and review of literature. *Nepal J Neurosci.* 2024;21(1):14–23. https://doi.org/10.3126/njn.v21i1.63309
3. Carone G, Bonada M, Belotti EG, D'Angeli E, Piccardi A, Doniselli FM, et al. Post-craniotomy infections: a point-by-point approach. *Brain Spine.* 2025;5:104193. https://doi.org/10.1016/j.bas.2025.104193
4. Chojak R, Koźba-Gosztyła M, Gaik M, Madej M, Majerska A, Soczyński O, et al. Meningitis after elective intracranial surgery: a systematic review and meta-analysis of prevalence. *Eur J Med Res.* 2023;28(1):184. https://doi.org/10.1186/s40001-023-01141-3
5. Kinaci A, Slot EMH, Kollen M, Germans MR, Amin-Hanjani S, Carlson AP, et al. Risk factors and management of incisional cerebrospinal fluid leakage after craniotomy: a retrospective international multicenter study. *Neurosurgery.* 2023;92(6):1177–82. https://doi.org/10.1227/neu.0000000000002345
6. Katayama Y, Kitamura T, Kiyohara K, Sado J, Hirose T, Matsuyama T, et al. Factors associated with posttraumatic meningitis among traumatic head injury patients: a nationwide study in Japan. *Eur J Trauma Emerg Surg.* 2021;47(1):251–9. https://doi.org/10.1007/s00068-019-01224-z
7. Di G, Zhang Y, Liu H, Jiang X, Liu Y, Yang K, et al. Postoperative complications influencing the long-term outcome of head-injured patients after decompressive craniectomy. *Brain Behav.* 2019;9(1):e01179. https://doi.org/10.1002/brb3.1179
8. Schröder I, Güresir E, Vatter H, Soehle M. Single-centre real-life observational study on mortality and outcomes: decompressive craniectomy and brain death in traumatic brain injury, haemorrhage, and other cerebral diseases. *Acta Neurochir (Wien).* 2024;166(1):283. https://doi.org/10.1007/s00701-024-06170-3
9. Kourbeti IS, Vakis AF, Papadakis JA, Karabetsos DA, Bertsias G, Filippou M, et al. Infections in traumatic brain injury patients. *Clin Microbiol Infect.* 2012;18(4):359–64. https://doi.org/10.1111/j.1469-0691.2011.03625.x
10. Wang B, Zhang H, Hu Z. Retrospective analysis of prognostic factors after traumatic brain injury surgery. *Curr Probl Surg.* 2025;69:101797. https://doi.org/10.1016/j.cpsurg.2025.101797
11. Markakis K, Kapiki K, Edric AAA, Pappas AA, Feretos G, Nanoudis S, et al. Post-surgical central nervous system infections in the era of multidrug antibiotic resistance in Greece: a single-center experience of a decade. *Pathogens.* 2025;14(4):390. https://doi.org/10.3390/pathogens14040390
12. Magni F, Al-Omari A, Vardanyan R, Rad AA, Honeyman S, Boukas A. An update on a persisting challenge: a systematic review and meta-analysis of the risk factors for surgical site infection post craniotomy. *Am J Infect Control.* 2024;52(6):650–8. https://doi.org/10.1016/j.ajic.2023.11.005
13. Ndiaye Sy EHC, Cisse Y, Thiam AB, Barry LF, Mbaye M, Diop A, et al. Decompressive craniectomy: indications and results of 24 cases at the neurosurgery clinic of Fann University Hospital of Dakar. *Pan Afr Med J.* 2021;38:399. https://doi.org/10.11604/pamj.2021.38.399.27571