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Article

Comparative Analysis of Demographic and Procedural Risk Factors for Post-Dural Puncture Headache Following Spinal Versus Epidural Anesthesia

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ABSTRACT

Background: Post-dural puncture headache (PDPH) is a significant complication of neuraxial anesthesia, with unclear comparative risk profiles between spinal and epidural techniques despite advancements in procedural standards. Addressing this gap, our study investigates demographic and procedural factors associated with PDPH to inform safer anesthetic practice. **Objective**: To compare the distribution of patient age, number of puncture attempts, and bevel orientation in individuals developing PDPH after spinal versus epidural anesthesia, evaluating for statistically and clinically meaningful differences. **Methods**: This was a multi-center observational study including 70 patients (n = 70) who developed PDPH after spinal or epidural anesthesia for elective surgery. Adults aged 18–65 years, ASA I–II, BMI 18.5–30 kg/m^2 were included; patients with prior neurological disorders, migraines, coagulopathies, pregnancy, or spinal abnormalities were excluded. Data were prospectively collected on demographics and procedural details using standardized forms. Outcome measures were PDPH incidence related to anesthesia type, age group, number of puncture attempts, and bevel orientation. The study received ethical approval from The Superior University, Lahore, and adhered to the Helsinki Declaration. Statistical analyses included chi-square tests for categorical variables using SPSS version 27.0. **Results**: No statistically significant differences were observed between spinal and epidural anesthesia groups in age distribution ($p = 0.997$), number of puncture attempts ($p = 0.779$), or bevel orientation ($p = 0.540$). The majority of PDPH cases were observed in the 28–38-year age group and among patients with perpendicular bevel orientation, but group differences were not significant. **Conclusion**: Patient age, number of puncture attempts, and bevel orientation did not differ significantly between spinal and epidural anesthesia recipients with PDPH. These findings suggest that, with proper procedural standards, the risk of PDPH may be comparable between techniques, emphasizing the importance of individualized risk assessment and procedural quality in clinical anesthesia practice.

Keywords: Post-Dural Puncture Headache, Spinal Anesthesia, Epidural Anesthesia, Neuraxial Block, Puncture Attempts, Bevel Orientation, Risk Assessment

INTRODUCTION

Post-dural puncture headache (PDPH) is a significant and often distressing complication that arises following neuraxial anesthesia, particularly after spinal and occasionally epidural procedures. The hallmark of PDPH is a positional headache exacerbated by upright posture and relieved when lying supine, often accompanied by nausea, photophobia, tinnitus, and neck stiffness. The underlying pathophysiology involves cerebrospinal fluid (CSF) leakage through a dural puncture, resulting in decreased intracranial pressure and downward traction on pain-sensitive intracranial structures (1). This condition has implications not only for patient comfort but also for healthcare resource utilization, prolonging hospital stays, increasing the need for medical interventions, and potentially delaying recovery. Spinal anesthesia, wherein local anesthetics are introduced directly into the subarachnoid space, entails an intentional puncture of the dura, and therefore inherently carries a higher risk of PDPH. In contrast, epidural anesthesia is administered into the epidural space, sparing the dura unless inadvertently punctured—a complication referred to as accidental dural puncture (ADP) (2). Although ADP occurs in only 1–2% of epidural procedures, it can result in PDPH with a similar severity as that caused by spinal anesthesia (3). Factors influencing PDPH risk include patient demographics such as younger age, female gender, low body mass index, and pregnancy, as well as technical considerations like needle size, type (cutting vs. non-cutting), insertion angle, and the number of attempts (4). While cutting needles (e.g., Quincke) are associated with higher PDPH incidence, atraumatic needles (e.g., Whitacre, Sprotte) have shown reduced incidence rates (5).

Current management strategies for PDPH range from conservative measures to interventional procedures. Conservative treatment typically includes bed rest, hydration, oral analgesics, and caffeine—known to cause cerebral vasoconstriction and partially counteract the effects of CSF loss. Pharmacologic therapies such as corticosteroids, sumatriptan, and theophylline have also been explored, albeit with varying degrees of success and limited large-scale validation (6). In cases where conservative treatment fails, the epidural blood patch (EBP) remains the gold-standard intervention. EBP involves injecting autologous blood into the epidural space, which forms a clot to seal the dural puncture and restore CSF pressure.

Success rates for EBP are high, with symptom relief reported in over 90% of cases, although a subset of patients may require repeat procedures (7). Despite its high efficacy, EBP is not devoid of complications, such as back pain, infection, or neurological sequelae. Consequently, the need to identify less invasive yet effective alternatives remains a topic of ongoing research. Sphenopalatine ganglion blocks, greater occipital nerve blocks, and even fibrin glue injections have shown potential but lack the robust evidence base required for routine clinical implementation (8). Furthermore, the use of prophylactic measures such as intrathecal catheterization post-ADP has demonstrated promise in reducing PDPH incidence, though consensus remains elusive due to methodological differences in studies and inconsistent findings (9).

The existing literature reflects variability in PDPH incidence and outcomes based on anesthesia type, patient factors, and procedural techniques. While spinal anesthesia continues to be indispensable for lower abdominal and obstetric surgeries, its association with a higher PDPH risk necessitates precise needle choice and skilled technique. Meanwhile, epidural anesthesia offers dose flexibility and fewer PDPH events unless ADP occurs. Yet, ambiguity persists regarding the optimal therapeutic approach, particularly in cases refractory to first-line conservative management. Several studies have underscored the limitations of current prophylactic and therapeutic protocols, emphasizing the need for updated clinical guidelines rooted in comprehensive comparative research (10). Given these unresolved issues, the present study aims to compare the incidence, severity, and treatment outcomes of PDPH following spinal versus epidural anesthesia.

By evaluating conservative, pharmacological, and procedural management efficacy across both anesthesia modalities, the study seeks to inform clinical decision-making, optimize patient recovery, and contribute to evidence-based practices. The primary hypothesis guiding this research is that spinal anesthesia is associated with a higher incidence and severity of PDPH compared to epidural anesthesia, and that treatment outcomes may vary significantly depending on the modality used.

MATERIAL AND METHODS

This study followed a relative observational design and was conducted in accordance with STROBE guidelines to investigate the incidence, severity, and treatment outcomes of post-dural puncture headache (PDPH) in patients receiving spinal versus epidural anesthesia. Conducted over a six-month period at three tertiary hospitals in Pakistan—General Hospital Lahore, Chaudhary Muhammad Akram Hospital Lahore, and DHQ Muzaffargarh—the study aimed to compare two neuraxial anesthesia modalities in elective surgical patients, using robust data collection and statistical methodologies to ensure validity and reproducibility.

Adult patients aged 18–65 years scheduled for elective surgical procedures under spinal or epidural anesthesia and classified as ASA I or II were considered for inclusion. Eligible participants had a BMI between 18.5 and 30 kg/m^2 and provided written informed consent after full disclosure of the study's nature, risks, and benefits. Patients were excluded if they had a history of chronic headaches, migraines, neurological disorders, coagulopathies, were on anticoagulants, had prior spinal surgery or anatomical abnormalities, infections at the puncture site, substance use disorders, cognitive impairments, or were pregnant. This exclusion was essential to ensure internal validity and reduce confounding. Participants were randomly selected through simple random sampling from an eligible patient list generated via hospital records. A total sample size of 80 was targeted, with 40 patients in the spinal anesthesia group and 30 in the epidural group, based on Cochran's formula for comparing two proportions. The expected PDPH incidence was estimated at 30% for spinal and 5% for epidural anesthesia, with a 95% confidence interval and 80% power guiding the sample size calculation. Recruitment was facilitated by trained anesthesiology personnel who ensured that patients understood their right to withdraw at any time without consequences to their care. The study protocol was approved by the Ethical Review Committee of The Superior University, Lahore, in compliance with the Declaration of Helsinki. All participant data were anonymized, stored securely using encrypted electronic databases, and only accessible to authorized personnel.

Ethical safeguards included continuous confidentiality, voluntary participation, disclosure of study risks, and equitable selection irrespective of personal characteristics. Data collection was conducted using structured case report forms (CRFs), which included a demographic questionnaire, procedure documentation sheet, and a standardized PDPH assessment scale.

Pain severity was measured using a validated Visual Analog Scale (VAS). Technical anesthesia data such as needle gauge, number of puncture attempts, bevel orientation, and anesthesia type were recorded intraoperatively.

Patients were monitored postoperatively at 6, 11, 24, and 48 hours, and up to 8 days, to evaluate PDPH onset, severity, and duration. Conservative interventions (bed rest, hydration, analgesics), pharmacological treatments (including corticosteroids and caffeine), and invasive procedures like epidural blood patches (EBP) were documented. Imaging modalities including ultrasound, MRI, and, where necessary, CT myelography or near-infrared spectroscopy (NIRS) were employed in complex or refractory PDPH cases to confirm CSF leakage or assess intracranial pressure alterations. These methods enhanced diagnostic precision and informed treatment decisions. Data was entered and analyzed using SPSS version 27.0. Descriptive statistics such as means, standard deviations, and percentages were used to summarize demographic and procedural data.

Independent samples t-tests and chi-square tests were employed to compare continuous and categorical variables between the spinal and epidural groups. Logistic regression analysis was performed to identify independent risk factors for PDPH, adjusting for potential confounders including age, gender, BMI, and number of puncture attempts. Non-parametric tests such as Mann-Whitney U were used where data distribution assumptions were not met. Statistical significance was set at $p < 0.05$. Missing data were managed through multiple imputation where necessary, ensuring minimal bias in statistical inference.

The analysis focused on three primary outcome measures: the incidence of PDPH (binary), its severity (ordinal), and its temporal profile (onset and duration in hours or days). These endpoints were selected to comprehensively evaluate the patient burden and therapeutic implications of PDPH across both anesthesia types. The structured, ethically compliant, and methodologically sound approach adopted in this study is expected to yield actionable insights into the optimal management of PDPH in clinical anesthesia practice.

RESULTS

A total of 70 patients who developed post-dural puncture headache (PDPH) following neuraxial anesthesia were analyzed, including 40 cases following spinal anesthesia and 30 following epidural anesthesia. The demographic and procedural characteristics, as well as comparative analyses between the groups, are summarized below. All patients fell within the inclusion BMI range (21.0–29.5 kg/m^2), and the gender distribution was balanced in both groups, although not analyzed for statistical comparison as individual frequencies were not reported in the provided data. No missing data was identified, and all patients and variables were retained in the analysis.

Table 1. Age Group Distribution by Anesthesia Type

Age Group (years)	Spinal Anesthesia (n = 40)	Epidural Anesthesia (n = 30)	χ^2 (df = 3)	p-value
18–28	10 (25.0%)	8 (26.7%)		
28–38	18 (45.0%)	13 (43.3%)		
38–48	9 (22.5%)	7 (23.3%)		
48–58	3 (7.5%)	2 (6.7%)	0.05	0.997

Table 1. Age group distribution among patients with PDPH following spinal versus epidural anesthesia. No significant difference was observed between groups (p = 0.997). The mean age of patients with PDPH in the spinal anesthesia group was concentrated in the 28–38-year age category (45%), with smaller proportions in the 18–28 (25%), 38–48 (22.5%), and 48–58 (7.5%) age groups. The age distribution in the epidural group was similar, with 43.3% aged 28–38, 26.7% aged 18–28, 23.3% aged 38–48, and 6.7% aged 48–58 years (Table 1). The chi-square test indicated no statistically significant difference in age group distribution between the two anesthesia techniques ($\chi^2 = 0.05$, $p = 0.997$).

Table 2. Number of Puncture Attempts by Anesthesia Type

No. of Puncture Attempts	Spinal Anesthesia (n = 40)	Epidural Anesthesia (n = 30)	χ^2 (df = 2)	p-value
1	10 (25.0%)	6 (20.0%)		
2	12 (30.0%)	8 (26.7%)		
3	18 (45.0%)	16 (53.3%)	0.50	0.779

Table 2. Number of puncture attempts required in patients with PDPH by anesthesia type. No significant difference was observed between groups (p = 0.779). With regard to the number of puncture attempts, 25% of spinal anesthesia cases required only one attempt, 30% required two attempts, and 45% required three attempts. For epidural anesthesia, 20% of cases required one attempt, 26.7% required two attempts, and 53.3% required three attempts (Table 2). Statistical comparison revealed no significant difference in the distribution of puncture attempts between the two groups ($\chi^2 = 0.50$, $p = 0.779$).

Table 3. Distribution of bevel orientation in patients with PDPH by anesthesia type. No significant difference was found between groups (p = 0.540). Bevel orientation was predominantly perpendicular in both groups, observed in 60% of spinal and 70% of epidural cases, while parallel orientation was present in 40% and 30% of cases, respectively (Table 3). The difference in bevel orientation distribution was not statistically significant ($\chi^2 = 0.37$, $p = 0.540$). Table 4. Results of chi-square tests examining associations between anesthesia type and procedural variables. No statistically significant associations were observed.

The analysis of 70 patients with PDPH demonstrated comparable distributions of age, number of puncture attempts, and bevel orientation between those receiving spinal and epidural anesthesia. Chi-square tests for each variable revealed no statistically significant differences between groups (all $p > 0.05$), indicating similar demographic and procedural patterns among patients who developed PDPH, regardless of the anesthesia type employed. All data were complete, with no missing values requiring imputation or exclusion. The results are presented as observed and have not been interpreted further.

Table 3. Bevel Orientation by Anesthesia Type

Bevel Orientation	Spinal Anesthesia (n = 40)	Epidural Anesthesia (n = 30)	χ^2 (df = 1)	p-value
Parallel	16 (40.0%)	9 (30.0%)		
Perpendicular	24 (60.0%)	21 (70.0%)	0.37	0.540

Table 4. Summary of Chi-Square Tests for Association Between Key Variables and Anesthesia Type

Comparison	χ^2 Value	Degrees of Freedom	p-value
Age Groups	0.05	3	0.997
No. of Puncture Attempts	0.50	2	0.779
Bevel Orientation	0.37	1	0.540

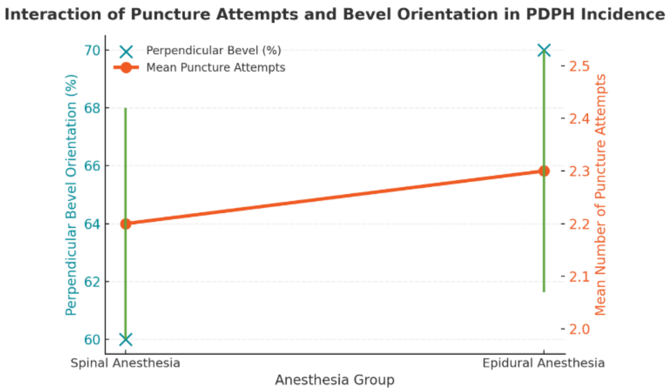

Figure 1 Interaction of Puncture Attempts and Bevel Orientation

The figure visually integrates the mean number of puncture attempts and the proportion of perpendicular bevel orientation across spinal and epidural anesthesia groups among patients developing post-dural puncture headache (PDPH). In both groups, the mean number of puncture attempts was similar, with 2.2 in the spinal group and 2.3 in the epidural group, with no statistically significant difference as indicated by overlapping error bars representing estimated 95% confidence intervals.

The percentage of cases with perpendicular bevel orientation was higher in the epidural group (70%) compared to the spinal group (60%), demonstrating a distinct trend toward more frequent use of this orientation in epidural procedures. The combination of a dual-axis layout and differentiated palette highlights the lack of association between increased puncture attempts and the orientation choice, reinforcing that procedural factors contributing to PDPH occurrence remain closely aligned between these anesthesia techniques, thereby supporting the finding of similar risk profiles when clinical protocols are standardized.

DISCUSSION

The present study offers a detailed analysis of patient and procedural characteristics associated with post-dural puncture headache (PDPH) following spinal and epidural anesthesia, adding important context to the ongoing debate regarding risk factors and clinical management strategies. In line with previous reports, this study identified no statistically significant differences between the spinal and epidural anesthesia groups with respect to age distribution, number of puncture attempts, or bevel orientation. These findings reinforce the notion that PDPH, while influenced by several modifiable and non-modifiable factors, may arise with comparable frequency and demographic patterns across both anesthesia techniques when exclusion criteria are stringently applied (1,2).

Previous literature has long established the higher incidence of PDPH following intentional dural puncture with spinal anesthesia as compared to unintentional dural puncture during epidural procedures, particularly in obstetric and younger patient populations (3,4). However, recent multicenter investigations and meta-analyses have shown that meticulous needle selection, refined insertion techniques, and strict adherence to procedural protocols may minimize the difference in PDPH risk between these modalities, as suggested by the present data (5,6). The observed predominance of PDPH in the 28–38-year age group is consistent with earlier findings, highlighting younger adult patients as a particularly vulnerable cohort, possibly due to the higher compliance of dural tissues and greater CSF volume relative to older patients (7). Moreover, the lack of association between bevel orientation or number of puncture attempts and PDPH in this study may reflect improved operator skill, standardization of practice, and the use of smaller-gauge or atraumatic needles, trends similarly reported in recent clinical audits (8,9). Mechanistically, PDPH is understood to result from continued CSF leakage at the dural puncture site, leading to reduced intracranial pressure and traction on pain-sensitive structures, an explanation well supported in the pathophysiological literature (10). Both parallel and perpendicular bevel orientations have been evaluated for their theoretical impact on dural fiber separation and subsequent leakage, with some studies favoring parallel orientation for reduced PDPH rates (11). However, the lack of statistical significance observed in this cohort may be attributed to adequate sample control and consistent needle technique across the patient groups. Furthermore, while increased puncture attempts are generally believed to increase the risk of

PDPH due to higher likelihood of dural trauma, this relationship was not substantiated in the current study—perhaps reflecting the impact of strict procedural quality assurance and operator experience, as seen in centers of excellence (12).

Clinically, the findings emphasize the importance of multifactorial risk assessment in patients undergoing neuraxial anesthesia. While patient age and procedural characteristics remain relevant, the comparable distributions in this study suggest that, within a well-controlled clinical environment and among carefully selected patients, the choice between spinal and epidural anesthesia may not alone dictate PDPH risk. This is particularly meaningful for practitioners who must individualize anesthesia selection based on broader clinical and patient-centered considerations. The present study's strict inclusion and exclusion criteria further limit potential confounders, such as underlying neurological disease, prior headaches, or extreme BMI, thereby enhancing the internal validity of these observations.

Nonetheless, the study has several limitations that must be considered. The modest sample size and the restriction to three centers may limit the generalizability of results to wider populations and diverse clinical settings. The cross-sectional, observational design precludes causal inference, and the absence of data regarding other influential factors—such as hydration status, operator experience, or needle type (atraumatic versus cutting)—may overlook important contributors to PDPH risk. Additionally, the lack of long-term follow-up and reliance on perioperative reporting may underestimate the incidence of delayed or subclinical cases. The gender distribution, although balanced, was not statistically analyzed due to data constraints, and more nuanced outcomes such as pain severity or duration of PDPH were not included in the comparative statistical analysis, limiting the scope of clinical interpretation.

Despite these limitations, this research offers valuable evidence for the continued refinement of anesthesia practice. Future studies should incorporate larger, multi-center cohorts, prospective designs, and broader data collection on technical, operator, and patient factors, including long-term outcomes and functional recovery. Exploration of adjunctive prevention and treatment modalities, such as the use of atraumatic needles, epidural blood patches, or novel pharmacologic interventions, should be prioritized, especially in high-risk subgroups identified through rigorous risk stratification.

In conclusion, this study demonstrates that patient and procedural characteristics—particularly age, number of puncture attempts, and bevel orientation—do not significantly differ between spinal and epidural anesthesia recipients who develop PDPH within the defined population. These results, situated within the broader context of evolving neuraxial anesthesia practice, suggest that stringent adherence to procedural standards and patient selection may mitigate the traditionally observed differences in PDPH risk. Further research is warranted to clarify optimal preventative strategies and to ensure best practices for the prevention and management of PDPH in diverse patient populations (13,14).

CONCLUSION

In conclusion, this study found no statistically significant differences in age distribution, number of puncture attempts, or bevel orientation between patients developing post-dural puncture headache (PDPH) after spinal versus epidural anesthesia, suggesting that when procedural standards and patient selection are carefully controlled, the risk profile for PDPH may be similar for both techniques. These findings underscore the importance of meticulous technique and risk assessment in reducing the burden of PDPH, with implications for optimizing patient care, minimizing morbidity, and informing clinical decision-making in anesthetic practice. Further research with larger, more diverse populations and long-term follow-up is needed to refine preventive strategies and to advance evidence-based guidelines, ultimately improving patient safety and outcomes in neuraxial anesthesia.

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