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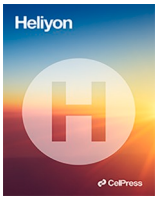

Research article

Factors associated with an inadvertent dural puncture or post-dural puncture headache following labour epidural analgesia: A retrospective cohort study

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ABSTRACT

Inadvertent dural puncture and post-dural puncture headache are complications of labour epidural analgesia and may result in acute and chronic morbidity. Identification of risk factors may enable pre-emptive management and reduce associated morbidity. In this retrospective cohort study, we aimed to identify factors associated with an inadvertent dural puncture or post-dural puncture headache by identifying parturients who received labour epidural analgesia from January 2017 to December 2021. The primary outcome was any witnessed inadvertent dural puncture, inadvertent placement of an intrathecal catheter, clinical diagnosis of post-dural puncture headache, or headache that was assessed to have characteristic post-dural puncture headache features. A wide range of demographic, obstetric, and anaesthetic factors were analysed using univariate and multivariable analyses to identify independent associations with the primary outcome.

Data from 26,395 parturients were analysed, of whom 94 (0.36%) had the primary outcome. Within these 94 parturients, 26 (27.7%) had inadvertent dural puncture, 30 (31.9%) had inadvertent intrathecal catheter, and 38 (40.4%) had post-dural puncture headache without documented inadvertent dural puncture or intrathecal catheter insertion. Increased number of procedure attempts (adjusted odds ratio 1.39, 95% confidence interval 1.19 to 1.63), longer procedure duration adjusted odds ratio 1.03, 95% confidence interval 1.01 to 1.05), increased depth of epidural space (adjusted odds ratio 1.10, 95% confidence interval 1.04 to 1.18), greater post-procedure Bromage score (adjusted odds ratio 7.70, 95% confidence interval 4.22 to 14.05), and breakthrough pain (adjusted odds ratio 3.97, 95% confidence interval 2.59 to 6.08) were independently associated with increased odds of the primary outcome, while the use of standard patient-controlled epidural analgesia (PCEA) regimen (adjusted odds ratio 0.50, 95%confidence interval 0.31 to 0.81), increased concentration of ropivacaine (adjusted odds ratio 0.08 per 0.1%, 95% confidence interval 0.02 to 0.46), and greater satisfaction score (adjusted odds ratio 0.96, 95% confidence interval 0.95 to 0.97) were associated with reduced odds. The area under curve of this multivariable model was 0.83.

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We identified independent association factors suggesting that greater epidural depth and procedure difficulty may increase the odds of inadvertent dural puncture or post-dural puncture headache.

1. Introduction

Epidural analgesia is generally considered the reference standard for labour pain relief and is employed in up to 83% of parturients in developed countries [1]. Inadvertent dural puncture and post-dural puncture headache (PDPH) are well-described complications of labour epidural analgesia, with 0.2%–4.4% of parturients experiencing inadvertent dural puncture [2], of whom 50%–85% develop PDPH [3,4]. The International Headache Society defines PDPH as a headache occurring within five days of a dural puncture that is caused by cerebrospinal fluid leakage [5]. PDPH is often characterised as positional, with its intensity worsening in the upright position and relieved by lying supine, and may be accompanied by neck stiffness, tinnitus, photophobia, dizziness, nausea, cranial nerve palsy, and subdural haematoma [3,6]. In addition to hindering maternal recovery and infant care, delaying hospital discharge, and increasing healthcare workload [7], mounting evidence shows that inadvertent dural puncture or PDPH are associated with debilitating longer-term morbidities such as chronic headache, backache, and postpartum depression [8]. Although several treatments have been proposed for PDPH, the epidural blood patch has proven effectiveness and is the current reference standard [9]. However, the epidural blood patch is an invasive procedure with potentially serious complications such as neuropathy, infection, and paraparesis [10–12]. Therefore, identification of risk factors for inadvertent dural puncture or PDPH may enable pre-emptive management to reduce morbidity associated with PDPH and the epidural blood patch. Unfortunately, available evidence regarding these risk factors is limited and conflicting, with some studies finding that nocturnal epidural analgesia, determining loss-of-resistance with air instead of saline, performing the procedure with the parturient sitting, increased cervical dilation, greater BMI or depth of epidural space, and operator inexperience were associated with increased risk of inadvertent dural puncture or PDPH [13–15], while other studies reported otherwise [16,17]. Hence, our primary objective was to identify independent association factors for inadvertent dural puncture or PDPH.

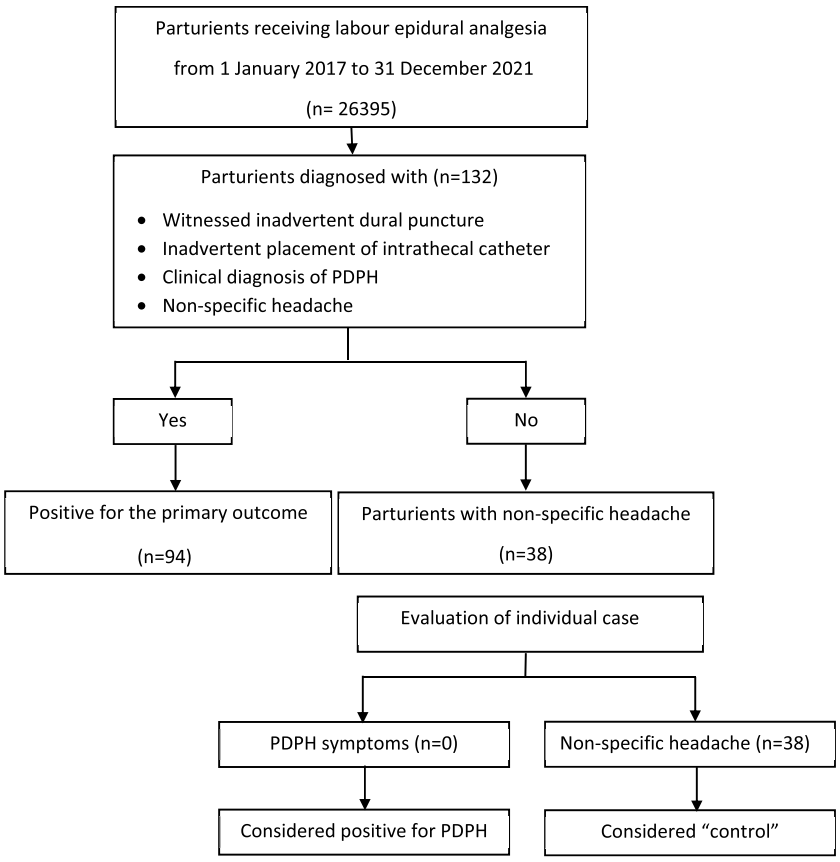

Fig. 1. Three-step protocol to identify parturients who experienced the primary outcome of inadvertent dural puncture or PDPH. PDPH, post-dural puncture headache.

2. Methods

This retrospective cohort study was approved by SingHealth Centralised Institutional Review Board (10 Hospital Boulevard #19-01 SingHealth Tower Singapore 168582; reference numbers 2021/2286 and CIRB 2022/2201; Chairperson Dr Steve Yang; approved on 27 May 2021 and 6 May 2022, respectively). This article adheres to the relevant Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines.

We employed a three-step protocol to identify parturients who experienced our primary outcome of inadvertent dural puncture or PDPH (Fig. 1). First, data on parturients who received labour epidural analgesia between 1 January 2017 to 31 December 2021 at KK Women's and Children's Hospital, Singapore were obtained from a database created to investigate complications arising from labour epidural analgesia. This database records demographic, anaesthetic, and obstetric data from all parturients who received labour epidural analgesia at KK Women's and Children's Hospital, in addition to complications such as inadvertent dural puncture, inadvertent placement of an intrathecal catheter, clinical diagnosis of PDPH, and postpartum headache that was not diagnosed as PDPH (e.g., migraine or tension headaches). All data were cross-checked by a dedicated research team, and missing data on covariates were obtained from a review of the clinical record, but if unavailable, the parturient was excluded from the analysis of that covariate. Next, parturients who experienced any of the following were considered positive for our primary outcome: (1) witnessed inadvertent dural puncture with the Tuohy needle, either documented as such by the anaesthesiologist or described as a steady flow of clear fluid from the Tuohy needle; (2) inadvertent placement of an intrathecal catheter, confirmed by aspiration of cerebrospinal fluid and/or clinical features suggestive of a subarachnoid block after an otherwise uneventful epidural procedure; and (3) clinical diagnosis of PDPH. Finally, to reduce misclassification bias, clinical records of parturients reporting headache during the routine postpartum follow-up at 24 h were individually assessed by two independent investigators, and those with features characteristic of PDPH (i.e. positional headache, with its intensity worsening in the upright position and relieved by lying supine, and may be accompanied by neck stiffness, tinnitus, photophobia, dizziness, nausea, cranial nerve palsy, and subdural haematoma) were considered positive for PDPH. Parturients who were negative for our primary outcome were classified as "controls".

As per institutional practice, epidural analgesia was achieved via combined spinal-epidural (CSE), with the standard epidural technique performed in the event of failure to obtain cerebrospinal fluid (CSF) during CSE. With the parturient in the sitting position, an 88 mm 18-gauge Tuohy needle (B. Braun, Germany) was inserted into the epidural space using the loss-of-resistance to saline technique, followed by needle-through-needle dural puncture using a 27-gauge Pencan® spinal needle. After intrathecal administration of 2 mg ropivacaine and 15 μg fentanyl, the spinal needle was withdrawn, and a 20-gauge soft tip multi-orifice catheter was threaded through the Tuohy needle. An epidural test dose of lignocaine 1% 3 mls was given at the discretion of anaesthesiologist. Epidural analgesia was maintained using a standard patient-controlled epidural analgesia (PCEA) regimen defined as: an infusion of 0.1%–0.125% ropivacaine with 2 $\mu g.ml^{-1}$ fentanyl at 8–12 ml h^{-1}, parturient-triggered bolus of 5 ml, and lockout period of 10 min.

In the event of inadvertent dural puncture, the anaesthesiologist had the option of inserting an intrathecal catheter through the Tuohy needle, re-siting the epidural at a different intervertebral space, or initiation of patient-controlled analgesia (PCA) remifentanil. Our institution employs protocolised management of inadvertent dural puncture or PDPH. This included bed rest, oral/intravenous fluid hydration (2–3 L per day), oral caffeine, and oral analgesics such as paracetamol, non-steroidal anti-inflammatory drugs (NSAIDs), and tramadol. Antiemetics and laxatives were also administered to avoid abdominal straining. If present, the spinal catheter was kept in situ for 24 h after the procedure and removed thereafter. Parturients with severe symptoms of PDPH, or in whom PDPH did not resolve after 48 h, were offered an epidural blood patch. Parturients who reported headache in the postpartum period that was not initially diagnosed as PDPH were monitored for at least 48 h for the development of symptoms characteristic of PDPH.

Data analysed included age, race, body mass index (BMI), American Society of Anaesthesiologists (ASA) physical status, parity, comorbidity, mode of labour onset, pre-procedure pain score, cervical dilation at the time of the procedure, number of anaesthesiologists performing the procedure, seniority of the anaesthesiologist, neuraxial technique, PCEA regimen, number of procedure attempts, procedural duration, time of the procedure, depth of epidural space, and ropivacaine concentration. Following the procedure, we analysed data regarding pain score (0: no pain, 10: worst pain imaginable), sensory level (defined as the dermatomal level at which the parturient reported the same cold sensation to ice compared to the shoulder), modified Bromage score (0: able to flex hip, 1: able to flex knee but not hip, 2: able to flex ankle only, 3: unable to flex ankle), development of breakthrough pain, pain score at time of breakthrough pain, and satisfaction score at 24 h (0: very dissatisfied to 100: very satisfied). We also reported the incidence of epidural blood patch, PDPH symptoms, and hospital readmission due to PDPH.

2.1. Statistical analysis

The primary outcome was treated as binary data with categories "yes" or "no". All parturient and clinical variables were summarised based on the presence or absence of the primary outcome. Continuous and categorical variables were summarised as mean (standard deviation, SD) or frequency (proportion) respectively. Differences between PDPH categories were tested using two-sample *t*-test or Chi-Square tests for continuous and categorical variables, respectively. To determine factors associated with our primary outcome, univariate and multivariable logistic regression analyses were performed. The final multivariable model was determined using stepwise variable selection method. Quantitative associations from logistic regression model were expressed as odds ratio (OR) with 95% confidence intervals (95%CI). The overall performance of the final multivariable was evaluated using area under the curve (AUC) of receivers' operating characteristics (ROC) curve. P-values <0.05 were considered statistically significant and all tests were two-sided. Analyses were performed using SAS version 9.4 (SAS Institute; North Carolina, USA).

3. Results

We analysed data from 26,395 parturients who received labour epidural over the five-year study period, of whom 132 were evaluated for our primary outcome. Of these 132 parturients, 38 were determined to have postpartum headaches without characteristic PDPH symptoms, yielding 94 parturients (0.36%, 95%CI 0.28 to 0.44) that experienced the primary outcome (Table 1). Out of these 94 parturients, 26 (27.7%) had an inadvertent dural puncture, 30 (31.9%) had an inadvertent intrathecal catheter, and 38 (40.4%) had PDPH without documented inadvertent dural puncture or intrathecal catheter insertion.

Demographic and obstetric characteristics are summarised in Table 2. Overall, apart from Indian race (unadjusted OR (uOR) 1.79, 95%CI 1.02 to 3.17) and higher body mass index (BMI) (uOR 1.04, 95%CI 1.00 to 1.07) that were associated with the primary outcome in univariate analyses, no other significant differences were noted between the groups.

Details of the labour epidural analgesia are summarised in Table 3. Univariate analyses identified a greater number of anaesthesiologists performing the procedure, procedures performed by Fellows, use of standard epidural technique (instead of CSE), no PCEA or use of non-standard PCEA regimens, increasing number of procedure attempts, longer procedure duration, increasing depth to epidural space, higher post-procedure Bromage score, sensory block levels cephalad or caudad to T7 to T10 dermatomes, breakthrough pain, and higher pain scores at the time of breakthrough pain as factors that were associated with the primary outcome. Conversely, procedures performed by consultants, use of the standard PCEA regimen, higher ropivacaine concentrations, and higher satisfaction scores were associated with lower odds of developing our primary outcome in univariate analyses.

Table 4 summarises the management of epidural analgesia and symptoms of parturients who experienced the primary outcome. Of the 56 parturients who had an inadvertent dural puncture or inadvertent intrathecal catheter, all of them received labour analgesia via an intrathecal catheter that was inserted through the Tuohy needle in the former or left in-situ in the latter. Of note, 13 of these 56 parturients did not develop PDPH symptoms. Out of the 94 parturients who experienced the primary outcome, 10 (10.6%) required a repeat neuraxial procedure, and 1 (1.1%) required conversion to PCA remifentanil as the intrathecal catheter did not provide adequate pain relief. Also, 12 (12.8%) parturients required treatment with an epidural blood patch, and 10 (10.6%) were readmitted due to the development of PDPH symptoms following hospital discharge. The most common symptoms reported were postural headache (n = 81, 86.2%), neck stiffness (n = 29, 30.9%), and tinnitus (n = 8, 8.5%). Most symptoms were reported within 24 h after the procedure (n = 53, 56.4%).

Multivariable analysis identified eight variables independently associated with the primary outcome (Table 5), with greater number of procedure attempts (adjusted OR (aOR) 1.39, 95%CI 1.19 to 1.63), longer procedure duration (aOR 1.03, 95%CI 1.01 to 1.05), increased depth of epidural space (aOR 1.10, 95%CI 1.04 to 1.18), higher post-procedure Bromage score (aOR 7.70, 95%CI 4.22 to 14.05), and breakthrough pain (aOR 3.97, 95%CI 2.59 to 6.08) associated with increased odds of experiencing the primary outcome. Conversely, use of the standard PCEA regimen (aOR 0.50, 95%CI 0.31 to 0.81), increased concentration of ropivacaine (aOR 0.08 per 0.1%, 95%CI 0.02 to 0.46), and increased satisfaction score (aOR 0.96, 95%CI 0.95 to 0.97) were associated with lower odds of developing the primary outcome. The AUC of this multivariable model was 0.83.

4. Discussion

In this five-year retrospective cohort study, we estimated that 0.36% of parturients experienced inadvertent dural puncture, inadvertent intrathecal catheter, or PDPH. We also found that a greater number of procedure attempts, longer procedure duration, increased depth of epidural space, higher post-procedure Bromage score, and breakthrough pain were independently associated with increased odds of experiencing the primary outcome, while the use of the standard PCEA regimen, increased concentration of ropivacaine, and increased satisfaction score reduced the odds of developing the primary outcome.

Table 1
Number of parturients experiencing inadvertent dural puncture, inadvertent intrathecal catheter, post-dural puncture headache (PDPH), or postpartum headache without characteristic PDPH symptoms.

Events/Year	2017	2018	2019	2020	2021	Total
Inadvertent dural puncture[a]	3	3	2	8	10	26
Inadvertent intrathecal catheter[b]	10	10	5	2	3	30
Post-dural puncture headache[c]	8	13	7	8	2	38
Postpartum headache without characteristic PDPH symptoms[d]	11	6	2	3	16	38
Primary outcome[e]	21	26	14	18	15	94
Number of labour epidurals	5,022	5,212	5,029	5,314	5,818	26,395
Incidence of primary outcome (%)	0.42	0.5	0.28	0.34	0.26	0.36

[a] Witnessed inadvertent dural puncture with the Tuohy needle, either documented as such by the anaesthesiologist or described as a steady flow of clear fluid from the Tuohy needle.

[b] Inadvertent placement of an intrathecal catheter, confirmed by aspiration of cerebrospinal fluid and/or clinical features suggestive of a subarachnoid block after an otherwise uneventful epidural procedure.

[c] Clinical diagnosis of PDPH, and parturients reporting non-specific headache that were assessed to have characteristic PDPH symptoms.

[d] Parturients who reported non-specific headache without characteristic features of PDPH.

[e] Primary outcome was defined as any of following: inadvertent dural puncture; inadvertent intrathecal catheter; clinical diagnosis of PDPH; and parturients reporting non-specific headache during the routine postpartum follow-up at 24 h assessed to have features characteristic of PDPH.

Table 2
Demographic, and obstetric characteristics of parturients who experienced inadvertent dural puncture or PDPH, versus those who did not.

Characteristics	Inadvertent dural puncture or PDPH (n = 94)	No inadvertent dural puncture or PDPH (n = 26,301)	Unadjusted OR (95% CI)	P-value
Age (years)	30.7 ± 4.5	30.9 ± 4.8	0.99 (0.95–1.03)	0.6618
Race				0.056[a]
Chinese	40 (42.6%)	12,078 ± 45.9	Reference	–
Malay	25 (26.6%)	6,026 ± 22.9	1.25 (0.76–2.07)	0.378
Indian	17 (18.1%)	2,864 ± 10.9	1.79 (1.02–3.17)	0.044
Others	12 (12.7%)	5,333 ± 20.3	0.68 (0.36–1.30)	0.241
Weight (kg)	71.8 ± 15.3	69.2 ± 13.7	1.01 (1.00–1.03)	0.067
Height (cm)	160.0 ± 10.0	160.0 ± 10.0	0.60 (0.01–25.23)	0.789
BMI ($kg.m^{-2}$)	28.5 ± 5.7	27.4 ± 5.1	1.04 (1.00–1.07)	0.043
ASA physical status[b]				0.173[a]
I	63 (67.0%)	17,006 (64.7%)	Reference	–
II	27 (28.7%)	8,813 (33.5%)	0.83 (0.53–1.30)	0.410
III	4 (4.3%)	482 (1.8%)	2.24 (0.81–6.18)	0.119
Parity				
Nulliparous	58 (61.7%)	15,787 (60.0%)	1.07 (0.71–1.63)	0.740
Multiparous	36 (38.3%)	10,520 (40.0%)	0.93 (0.61–1.14)	0.737
Direct morbidity (e.g. PIH)	2 (2.1%)	216 (0.8%)	2.63 (0.64–10.72)	0.179
Indirect morbidity (e.g. CVS problems)	1 (1.1%)	40 (0.6%)	7.06 (0.96–51.90)	0.055
Labour onset				
Spontaneous	43 (45.7%)	14,204 (54%)	0.72 (0.48–1.08)	0.110
Prostin use[c]	34 (36.2%)	7,605 (28.9%)	1.39 (0.91–2.12)	0.123
Artificial rupture of membranes	18 (19.1%)	4,995 (19%)	1.00 (0.60–7.70)	0.971
Number of Prostin tablets used	0.4 ± 0.9	0.3 ± 0.6	1.32 (1.03–1.69)	0.029
Cervical dilation at time of procedure (cm)	3.6 ± 1.1	3.5 ± 1.0	1.15 (0.94–1.39)	0.173

Values are mean ± SD or number (proportion).
ASA, American Society of Anesthesiologists. BMI, body mass index. CI, confidence interval. CVS, cardiovascular system. PDPH, post-dural puncture headache. OR, odds ratio. PIH, pregnancy-induced hypertension. SD, standard deviation.

[a] Type 3 p-value.

[b] Our institution defines ASA physical status score as I: healthy parturient; II: parturient with mild systemic disease; III: parturient with severe systemic disease; IV: parturient with severe systemic disease that is a constant threat to life. There was no ASA physical status IV parturients included in our dataset.

[c] Prostaglandin E2 suppository.

This incidence of 0.36% is lower than the 1% incidence of PDPH reported by other studies [18,19], although it is comparable to specialist obstetric centres with large volumes of labour epidural analgesia [20]. It is possible that increased experience with this procedure, coupled with closer supervision and rigorous training of junior anaesthesiologists, may have contributed to the low incidence at specialist obstetric centres such as ours. Nonetheless, this incidence was higher than the 0.15% reported by our prior study of the preceding nine years [20]. This discrepancy may be explained by the implementation of structured electronic records and revised institutional guidelines that improved postpartum screening for PDPH, which may have increased the detection rates for the primary outcome in this study. Current practice at our institution involves routine regular follow-up of parturients who experienced inadvertent dural puncture or intrathecal catheter and those patients with non-specific headaches to assess for development of PDPH. This follow-up is continued for at least 48 h in parturients who did not report any PDPH symptoms or until resolution of symptoms in parturients with PDPH. All clinical notes associated with these follow-up assessments are entered in structured electronic records, facilitating data extraction and accurate estimation of PDPH incidence. In contrast, institutional practice during our prior study involved ad hoc follow-up reviews and recording of data in non-structured clinical notes, which could have resulted in a lower detection rate for our primary outcome. Furthermore, to reduce misclassification bias, the current study incorporated another step of reviewing the clinical data of parturients who reported non-specific headaches to assess for characteristic PDPH symptoms, which may have contributed to the higher primary outcome incidence. Finally, it should be noted that most parturients presented within 24 h, which is consistent with other studies [21].

Our finding that increased depth to space was associated with our primary outcome is consistent with prior studies that identified increased depth to space and BMI as potential risk factors for inadvertent dural puncture or PDPH [16,22]. We postulate that increased adipose tissue, oedema, exaggerated lumbar lordosis, and difficulty achieving adequate lumbar spine flexion in these parturients may obscure anatomical landmarks, thereby increasing the difficulty of identifying the optimal needle insertion point and epidural space. In contrast, other studies, including a retrospective study by Miu et al. found no relationship between increased BMI and incidence of inadvertent dural puncture, incidence of PDPH, and need for epidural blood patch [23]. Although our study found a univariate association between higher BMI and the primary outcome, this association was not significant in multivariable analysis and may be attributable to the generally low BMI of our study population.

In addition, the association between a greater number of procedure attempts, longer procedure duration and breakthrough pain with the primary outcome suggests that difficulty with the epidural procedure increases the risk of inadvertent dural puncture and

Table 3
Details of labour epidural analgesia.

Characteristics	Inadvertent dural puncture or PDPH (n = 94)	No inadvertent dural puncture or PDPH (n = 26,301)	Unadjusted OR (95%CI)	P - value
Number of anaesthesiologists performing the procedure	1.0 ± 0.2	1.0 ± 0.1	3.52 (1.22–10.17)	0.020
Seniority of anaesthetist				0.012[a]
Registrar	43 (45.7%)	11,305 (43.0%)	Reference	–
Consultant	11 (11.7%)	5,860 (22.3%)	0.49 (0.25–0.96)	0.037
Fellow	1 (1.1%)	27 (0.1%)	9.74 (1.30–73.30)	0.027
Medical Officer	39 (41.5%)	9,098 (34.6%)	1.12 (0.73–1.74)	0.590
Neuraxial technique				
Combined spinal-epidural	85 (90.4%)	25,341 (96.3%)	Reference	–
Standard epidural	9 (9.6%)	960 (3.7%)	2.80 (1.40–5.57)	0.004
Loss-of-resistance technique				
Saline	92 (97.9%)	26,136 (99.4%)	Reference	–
Air	2 (2.1%)	165 (0.6%)	3.45 (0.84–14.10)	0.085
Standard PCEA regimen[b]	65 (69.1%)	23,032 (87.6%)	0.32 (0.21–0.49)	<0.001
No PCEA or non-standard PCEA regimens used[b]	24 (25.5%)	2,363 (9.0%)	3.47 (2.18–5.53)	<0.001
Number of procedure attempts[c]	1.8 ± 1.0	1.2 ± 0.7	1.48 (1.32–1.66)	<0.001
Procedure duration (minute)	14.1 ± 13.3	10.2 ± 6.8	1.05 (1.03–1.06)	<0.001
Depth of epidural space (cm)	5.4 ± 1.1	4.8 ± 1.1	1.10 (1.05–1.16)	<0.001
Concentration of ropivacaine (per 0.1%)	0.1 ± 0.0	0.1 ± 0.0	0.07 (0.01–0.33)	0.001
Pre-procedure pain score[d]	5.7 ± 3.5	5.6 ± 3.5	1.00 (0.90–1.40)	0.976
Post-procedure Bromage score[e]	0.1 ± 0.5	0.0 ± 0.1	7.31 (4.13–12.93)	<0.001
Post-procedure pain score[d]	0.4 ± 1.2	0.3 ± 1.0	1.11 (0.95–1.30)	0.183
Post-procedure sensory level[f]				<0.001[a]
T7/T8/T9/T10	47 (50%)	17,126 (65.1%)	Reference	–
T1/T2/T3	4 (4.3%)	206 (0.8%)	7.06 (2.53–19.82)	<0.001
T4/T5/T6	37 (39.4%)	8,040 (30.6%)	1.67 (1.09–2.58)	0.019
T11/T12/L1/L2	6 (6.4%)	927 (3.5%)	2.36 (1.01–5.53)	0.049
Breakthrough pain[g]	1.1 ± 1.4	0.2 ± 0.5	5.44 (3.63–8.16)	<0.001
Pain score at time of breakthrough pain[d]	2.7 ± 3.5	1.6 ± 2.6	1.14 (1.07–1.21)	<0.001
Satisfaction score[h]	81.1 ± 12.4	89.9 ± 9.4	0.95 (0.94–0.96)	<0.001

Values are mean ± SD or number (proportion).
CI, confidence interval. OR, odds ratio. PCEA, patient-controlled epidural analgesia. PDPH, post-dural puncture headache. SD, standard deviation.
[a] Type 3 p-value.
[b] Standard PCEA is defined as infusion of 0.1%–0.125% ropivacaine with 2 μg.ml^{-1} fentanyl at 8–12 ml h^{-1}, parturient-triggered bolus of 5 ml, and lockout period of 10 min.
[c] Number of procedure attempts defined as the number of skin punctures by the Tuohy needle.
[d] 11-point numerical rating scale. 0: no pain to 10: worst pain imaginable.
[e] Modified Bromage score. 0: able to flex hip, 1: able to flex knee but not hip, 2: able to flex ankle only, 3: unable to flex ankle, recorded by trained midwives.
[f] Defined as the dermatomal level at which the parturient reported the same cold sensation to ice compared to the shoulder.
[g] Breakthrough pain is defined as parturient complaints of pain or pressure requiring unscheduled supplemental epidural medication after the establishment of epidural labour analgesia.
[h] Satisfaction score. 0: very dissatisfied to 100: very satisfied.

PDPH. In this context, pre-procedure lumbar ultrasound may increase accuracy in determining the desired intervertebral level and midline while providing additional information regarding needle angulation and depth to the posterior complex (ligamentum flavum), which cannot be obtained through palpation alone [24,25]. A meta-analysis comparing ultrasound versus palpation techniques for lumbar neuraxial anaesthesia reported that the former significantly improved accuracy when estimating the intervertebral level and needle insertion depth while reducing the risk of technical failure and number of needle punctures compared to the standard technique [26]. However, the efficacy of lumbar ultrasonography in reducing the risk of inadvertent dural puncture and PDPH has not yet been firmly established and should be a focus of future research.

Furthermore, given the relationship between procedural difficulty and increased odds of inadvertent dural puncture or PDPH, it is possible that structured training and early referral of challenging epidurals to anaesthesiologists with greater experience may be beneficial. Our institution provides mandatory structured training to all junior anaesthesiologists, comprising of lectures, ten supervised procedures on a mannequin, ten supervised procedures on parturients, and three assessments. All junior anaesthesiologists must complete the above before they are permitted to perform epidurals independently [27]. Moreover, the Accreditation Council for Graduate Medical Education (ACGME) stipulates that anaesthesiology residents must complete 40 epidural procedures by the end of the junior residency. This is supported by an observational study by Lew et al. suggesting that a minimum of 40 epidural procedures is required to demonstrate competence [28]. The importance of structured training and early referral of challenging epidurals is underscored by our finding that procedures performed by consultants (senior anaesthesiologists) were associated with reduced risk of the primary outcome compared to registrars, while trainee anaesthesiologists were associated with increased risk.

Table 4
Management of epidural analgesia and postpartum symptoms of parturients who experienced the primary outcome.

Epidural analgesia characteristics	Inadvertent dural puncture or PDPH (n = 94)
Intrathecal catheter in-situ	56 (59.6%)
Repeat CSE/epidural procedure	10 (10.6%)
Initiation of PCA Remifentanil	1 (1.1%)
Epidural blood patch	12 (12.8%)
Readmission due to PDPH symptoms	10 (10.6%)
Procedure performed during call duty hours (1600–0830 h)	61 (64.9%)
Postpartum symptoms	
Postural headache	81 (86.2%)
Neck Stiffness	29 (30.9%)
Diplopia	0
Nausea/vomiting	5 (5.3%)
Tinnitus	8 (8.5%)
Pain score at 24 h after procedure[a]	4 ± 3.0
Duration of headache (days)	3.2 ± 2.2
Time from procedure to development of first symptom	
0–1 h	4 (4.3%)
1–24 h	53 (56.4%)
24–48 h	17 (18.1%)
>48 h	12 (12.8%)
No symptoms reported	8 (8.5%)

Values are mean ± SD or number (proportion).
CSE, combined spinal-epidural. PCA, patient-controlled analgesia. PDPH, post-dural puncture headache. SD, standard deviation.
[a] 11-point numerical rating scale. 0: no pain to 10: worst pain imaginable.

Table 5
Multivariable logistic regression model of factors associated with the primary outcome.

Variables	Adjusted OR (95% CI)	P - value
Standard PCEA regimen[a]	0.50 (0.31–0.81)	0.0044
Number of procedure attempts[b]	1.39 (1.19–1.63)	<0.0001
Procedure duration	1.03 (1.01–1.05)	0.0009
Depth of epidural space	1.10 (1.04–1.18)	0.0008
Concentration of ropivacaine (per 0.1%)	0.08 (0.02–0.46)	<0.0001
Post-procedure Bromage score[c]	7.70 (4.22–14.05)	<0.0001
Breakthrough pain[d]	3.97 (2.59–6.08)	<0.0001
Satisfaction score[e]	0.96 (0.95–0.97)	<0.0001

CI, Confidence interval; OR, Odds ratio. PCEA, patient-controlled epidural analgesia; PDPH, post-dural puncture headache.
[a] Standard PCEA is defined as infusion of 0.1%–0.125% ropivacaine with 2 μg.ml^{-1} fentanyl at 8–12 ml h^{-1}, parturient-triggered bolus of 5 ml, and lockout period of 10 min.
[b] Number of procedure attempts defined as the number of skin punctures by the Tuohy needle.
[c] Modified Bromage score. 0: able to flex hip, 1: able to flex knee but not hip, 2: able to flex ankle only, 3: unable to flex ankle.
[d] Breakthrough pain is defined as parturient complaints of pain or pressure requiring unscheduled supplemental epidural medication after the establishment of epidural labour analgesia.
[e] Satisfaction score. 0: very dissatisfied to 100: very satisfied.

We found that a higher Bromage score was associated with increased odds of the primary outcome; conversely, increased ropivacaine concentration and use of a standard PCEA regimen reduced these odds. All the parturients would receive the standard intrathecal 2 mg Ropivacaine with 15mcg of Fentanyl, which should not lead to a higher post-procedure Bromage score. The association of an increased Bromage score and our primary outcome of an inadvertent placement of an intrathecal catheter applies to the group of parturients with an unwitnessed dural puncture, which is discovered after the end of the procedure through a higher Bromage score and/or aspiration of CSF through the catheter. These higher Bromage scores may be due to the administration of the epidural lignocaine test dose, which went intrathecally, as the catheter inserted was in the intrathecal space. The association between increased ropivacaine concentration and lower odds of our primary outcome may reflect our institutional practice of administering 0.1% ropivacaine in parturients with an inadvertent dural puncture or intrathecal catheter, whereas parturients with epidural catheters receive up to 0.125% ropivacaine. A lower intrathecal ropivacaine concentration is advocated by our institution to facilitate early detection of neurological sequelae resulting from the intrathecal catheter; nonetheless, it should also be noted that delivering intrathecal ropivacaine 0.1% at 1–3 ml h^{-1} adheres to the latest recommendations for intrathecal labour analgesia [29]. Similarly, the association between the use of the standard PCEA regimen and reduced odds of the primary outcome may be due to our practice of avoiding PCEA in parturients suspected to have an inadvertent dural puncture or intrathecal catheter to reduce the risk of a high spinal blockade. Finally, inadvertent dural puncture or a diagnosis of intrathecal catheter may have reduced the use of CSE compared to other

forms of analgesia.

Our study's strengths include using a large, retrospectively collected dataset cross-checked by a dedicated research team. Most data analysed were extracted from structured clinical entries, facilitating data extraction, and reducing transcription errors. However, we acknowledge several limitations. First, the retrospective study design precluded analysis of other potential association factors, such as scoliosis or other structural spine abnormalities, which could have increased the risk of inadvertent dural puncture. Second, we acknowledge that not all cases of inadvertent dural punctures lead to PDPH; however, we included both inadvertent dural puncture and PDPH in our primary outcome based on a prior meta-analysis reporting that both outcomes are associated with long-term morbidity [8]. Third, although a dedicated research team attempted to obtain missing data from the clinical record, the accuracy of our results may be limited by the exclusion of parturients resulting from missing data. Fourth, we did not collect the analgesic requirements in the study population, which might suggest differential consumption of analgesics and pain scores between the groups. Of note, as standard practice in our institution, all postpartum patients receive oral paracetamol 1 gm 6 hourly and oral mefenamic acid 500 mg 8 hourly if they are not allergic to these medications. Oral tramadol 50 mg can be added in case of suboptimal analgesia or patients with an allergy to paracetamol/mefenamic acid. Finally, the dataset was obtained from a single centre with a predominantly Asian population who were generally healthy, had normal BMI, and received a CSE for labour analgesia. These practices may differ from other institutions, limiting our results' generalisability.

5. Conclusion

In summary, 0.36% of parturients experienced inadvertent dural puncture or PDPH, comparable to other specialist obstetric centres. Our findings also suggest that epidural procedural factors (e.g. greater depth to epidural space and procedural difficulty) and post-procedural outcomes (e.g. Bromage score, breakthrough pain and lower satisfaction scores) were associated with increased odds of inadvertent dural puncture or PDPH. Hence, we postulate that the use of ultrasonography, implementation of a structured training program, early referral of challenging epidurals to anaesthesiologists with greater experience and monitoring post-procedure Bromage score may be of benefit.

Ethics statement

This retrospective cohort study was approved by SingHealth Centralised Institutional Review Board (10 Hospital Boulevard #19-01 SingHealth Tower Singapore 168582; reference numbers 2021/2286 and CIRB 2022/2201).

Data availability statement

The datasets analysed during the current study are not publicly available but are available from the corresponding author on reasonable request.

CRediT authorship contribution statement

Avinash Kakde: Writing – original draft, Methodology, Investigation, Conceptualization. **Pamela Chia:** Writing – review & editing, Methodology, Investigation, Conceptualization. **Hon Sen Tan:** Writing – review & editing, Methodology, Investigation. **Rehena Sultana:** Writing – review & editing, Software, Resources, Methodology, Formal analysis. **Chin Wen Tan:** Writing – review & editing, Resources, Project administration, Methodology, Formal analysis, Data curation. **Ban Leong Sng:** Writing – review & editing, Supervision, Formal analysis, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2024.e27511.

Abbreviations

ACGME Accreditation Council for Graduate Medical Education
aOR adjusted Odd Ratio

ASA	American Society of Anaesthesiologist
AUC	Area Under Curve
BMI	Body Mass Index
CI	Confidence Interval
CSE	Combined Spinal Epidural
CSF	Cerebrospinal fluid
NSAIDS	Non-Steroidal Anti-inflammatory Drugs
OR	Odds Ratio
uOR	unadjusted Odds Ratio
PCA	Patient-controlled Analgesia
PCEA	Patient-controlled Epidural Analgesia
PDPH	Post-dural Puncture Headache
ROC	Receivers' Operating Characterestics
SD	Standard Deviation

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