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Review Article

OBSTETRICS

# Epidural analgesia *versus* dural puncture epidural analgesia in labouring parturients: a meta-analysis of randomised controlled trials

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## Abstract

**Background:** Epidural analgesia and dural puncture epidural (DPE) analgesia are widely used techniques for alleviating labour pain. This meta-analysis compared clinical outcomes between parturients receiving epidural analgesia *vs* DPE analgesia for labour pain.

**Methods:** Medical databases were searched to identify randomised controlled trials comparing epidural analgesia with DPE analgesia in labouring parturients published up to October 2024. Results were pooled using an inverse variance random-effects model, and 95% prediction intervals were calculated. Clinical outcomes were used as defined by individual trials. The primary outcome was time to onset of analgesia. Secondary outcomes were unilateral block, motor block, sacral sparing, adequate analgesia, Caesarean/operative vaginal delivery, additional doses, and hypotension. The certainty of evidence was assessed using Grading of Recommendations Assessment, Development, and Evaluation guidelines, and subgroup analyses were performed based on the types of local anaesthetics used.

**Results:** Eighteen trials involving 2144 parturients were included. DPE labour analgesia slightly reduced the time to onset (mean difference: 3.4 min, 95% confidence interval: 2.1–4.7, $P<0.01$, $I^2=97\%$; moderate certainty). All statistically significant results demonstrated clinical advantages for DPE analgesia, including fewer unilateral blocks, reduced motor block, improved sacral coverage, and higher rates of adequate analgesia. Substantial heterogeneity was observed in the outcome data for time to onset of analgesia, unilateral block, and sacral sparing. Pooled results for Caesarean/operative vaginal delivery, additional doses, and hypotension failed to achieve statistical significance.

**Conclusions:** DPE labour analgesia offers a slightly faster onset and reduced incidence of motor and unilateral blocks compared with traditional epidural analgesia. However, high heterogeneity in some outcomes, likely attributable to clinical and dosing variability, requires cautious interpretation. Although the clinical relevance of the faster onset with DPE analgesia might be modest, when considered alongside its benefits in secondary outcomes it supports the use of DPE analgesia over traditional epidural analgesia. Imputed prediction intervals cross zero for many outcomes, and further studies might alter these findings.

**Clinical trial registration:** PROSPERO- CRD42024602115.

**Keywords:** dural puncture epidural; labour analgesia; labour epidural; meta-analysis; unilateral labour analgesia

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### Editor's key points

- Epidural and dural puncture epidural (DPE) techniques effectively manage labour pain, but their comparative benefits remain uncertain.
- This meta-analysis revealed that DPE analgesia is associated with faster onset, fewer motor and unilateral block, and improved sacral sparing compared with epidural analgesia.
- The findings highlight the advantages of DPE analgesia in labour analgesia. Future research should address heterogeneity and assess its impact on labour duration and maternal satisfaction.

Dural puncture epidural (DPE) analgesia and traditional epidural analgesia are both commonly used anaesthetic techniques to provide labour analgesia for obstetric patients. Although both methods effectively alleviate pain, the comparative benefits and risks associated with each continue to be a topic of ongoing debate.[1] DPE analgesia involves intentional puncture of the dura mater, but without intrathecal injection of medication. The proposed advantages of DPE analgesia over traditional epidural analgesia include a faster onset of analgesia and an enhanced sensory block for a given anaesthetic dose.[2–4] However, uncertainty remains regarding these potential benefits,[5] and some clinicians may be concerned by the potentially increased risk of post-dural puncture headache (PDPH) and increased theoretical risk of seeding infections into the cerebrospinal fluid (CSF) because of breach in the dura mater. Additionally, DPE analgesia incurs higher costs because of the need for an additional spinal needle compared with epidural analgesia.

Previous meta-analyses and systematic reviews comparing DPE labour analgesia with epidural analgesia techniques[6,7] were limited by small sample sizes and missed trials, raising concerns about the generalisability of their conclusions. Additionally, the omission of prediction intervals by Yin and colleagues[7] may have masked variability in outcomes across different populations. Our study expands upon these earlier findings by utilising a larger dataset and uses advanced statistical methodologies, thereby enhancing the robustness and reliability of our conclusions regarding the efficacy of DPE analgesia. We focus on clinically relevant outcomes and comparisons of these two techniques to help guide clinical decision-making. Although this analysis focuses on pairwise comparison, it includes predictive modelling to estimate how future trials may influence the current evidence. By addressing previous limitations and offering more precise estimates of key outcomes, this review aims to provide clinicians with a comparison of the effectiveness and safety of DPE and traditional epidural analgesia in obstetric patients.

## Methods

### Overview

We performed a meta-analysis to compare the relative efficacy of DPE and epidural labour analgesia. The study protocol was registered with the International Prospective Register of Systematic Reviews (registration number: PROSPERO CRD42024602115). Our findings are reported according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) reporting guidelines.[8]

### Study eligibility

We reviewed randomised controlled trials (RCTs) that compared DPE labour analgesia with traditional epidural analgesia. An RCT was considered eligible if the reporting included information that matched our PICOTS criteria (defined below). We followed the following PICOTS[9] criteria:

- Population: labouring pregnant women aged 18 years or older.
- Intervention: patients receiving DPE labour analgesia. Different dosing techniques were included in the analysis without restrictions on the specific dosing protocols once the analgesia was initiated. All local anaesthetics were accepted, regardless of the type or method of administration (continuous or intermittent).
- Comparators: the comparator group comprised patients receiving conventional epidural labour analgesia.
- Outcomes: the primary outcome was the time required to achieve an adequate level of analgesia. We relied on the time reported by the trials, rather than on how each study specifically measured the adequacy of analgesia. Secondary outcomes included the comparative number of patients experiencing the following: motor block, hypotension, need for additional local anaesthetic top-ups, unilateral block, necessity for epidural catheter replacement, sacral sparing of analgesia, mode of delivery, Caesarean section rates, and the overall proportion of patients reporting adequate analgesia during the birthing process.
- Timing: all included patients were evaluated during the birthing process from the time of receiving either DPE or epidural analgesia.
- Setting: inpatient labour and delivery wards.

### Data sources

Two independent reviewers (PMS and MK) conducted a comprehensive literature search across Medline (PubMed), EMBASE, SCOPUS (Ovid), and the Cochrane Central Register of Controlled Trials for all RCTs published until October 2024. The following search terms were utilised: 'labour epidural analgesia' OR 'dural puncture epidural' AND 'time of onset' OR 'motor block' OR 'sacral sparing' OR 'Caesarean section rates' OR 'operative vaginal delivery' OR 'unilateral anesthesia' OR 'catheter replacement rates' OR 'side effects' OR 'hypotension' OR 'rescue analgesia' OR 'additional top-ups' OR 'adequate labour analgesia' OR 'nausea and vomiting rates'. No language restrictions were applied to the included manuscripts. Non-English trials were translated using an online translator (https://www.enago.com/translation/). Additionally, the reference lists of relevant publications and identified trials were hand-searched, and those meeting the above criteria were included in this analysis. Zotero version 5.0 (Corporation for Digital Scholarship, Vienna, VA, USA) was used to catalogue the references.

### Study selection

Two investigators (PMS and MK) independently assessed the abstracts and subsequently screened the full texts based on the eligibility criteria. Trials conducted on patients who underwent Caesarean delivery, rather than labour analgesia, were excluded. Likewise, trials involving combined spinal epidural (CSE) were also excluded. Any disagreements

regarding the eligibility of trials were resolved through consensus or, if necessary, by consulting a third author (AB).

### Data abstraction and outcome measures

Data were collected on trial design, year and country of publication, sample size, type of labour analgesia performed (DPE or epidural), and reported outcomes. We also extracted data regarding the nature of local anaesthetic, concentration of local anaesthetic, type of dosing regimen used, and tip and gauge of spinal needle. The extracted data were entered into Microsoft Excel (Microsoft Corporation, Redmond, WA, USA). For the included trials, we contacted the principal investigators via e-mail for additional information as needed to ensure complete data collection. Data reported as median and interquartile range (IQR) were converted to mean and standard deviation (SD) using Hozo's formula.

### Risk of bias assessment of individual trials

The risk of bias (ROB) was evaluated based on the Cochrane Collaboration's ROB2 criteria.[10] Two authors (AB and MK) independently assessed each trial to determine its ROB. For a trial to be classified as having a low ROB, all domains needed to be rated as low risk in the ROB assessment. The overall ROB was categorised as low risk, some concerns, or high risk.

### Certainty of evidence across trials

The overall certainty of evidence for pooled outcomes was evaluated using the Grading of Recommendations Assessment, Development, and Evaluation (GRADE) guidelines.[11] Two authors (PS and MK) independently reviewed the included trials to assess the certainty of the evidence. The extent of bias identified through these criteria was used to categorise the overall pooled outcomes, ranging from high quality to very low quality. Indirectness was assessed according to within-trial divergence across participants, interventions, and reported outcome characteristics.

### Statistical analysis

The pooled data were analysed using R with the meta (R Foundation for Statistical Computing, Vienna, Austria),[12] metafor (Metafor Software, Vancouver, BC, Canada),[13] and dmetar (GitHub, San Francisco, CA, USA) packages,[14] along with Comprehensive Meta-Analysis Version 3 (Biostat, Englewood, NJ, USA). The meta-analysis was conducted using the inverse variance method and a random-effects model. The inverse variance method weights trials based on the precision of their estimates, giving more weight to trials with smaller standard errors and allowing for more accurate pooled estimates. This contrasts with conventional meta-analytical methods where all trials may be weighted equally, potentially leading to biased results, especially when trial sizes vary significantly.

Dichotomous outcomes were reported as odds ratios (ORs), and continuous outcomes as mean differences (MDs), both with 95% confidence intervals (CIs), using the inverse variance method. Trial inconsistency was assessed using $I^2$ statistics, and inconsistency was considered significant if $I^2$ exceeded 50%.[15] Heterogeneity was further evaluated using a Baujat plot to identify trials contributing to heterogeneity. Forest plots were generated to visualise and evaluate treatment effects. All reported $P$-values were two-sided, with a threshold of $P<0.05$ considered statistically significant. We summarised outcomes for all parameters in a summary of findings (SoF) table. All outcome parameters were in SoF table based on GRADE recommendations.[11,16] This provides a concise summary of the estimated effect sizes for each outcome, the certainty of evidence (e.g. high, moderate, low, or very low), and critical contextual information such as absolute and relative effects.

Various exploratory subgroup analyses were conducted based on the type of local anaesthetics used in labour analgesia to explore differences between DPE and epidural analgesia techniques. Subgroups included the type of local anaesthetics used, and sensitivity analyses were performed to assess the robustness of the findings, including the leave-one-trial-out method. This approach was used to evaluate the contribution of each trial to the overall heterogeneity and to assess which trials had the most significant impact on the final effect size. Additionally, 95% prediction intervals were calculated using the meta package if the $P$-value for the outcome was statistically significant. This approach estimated potential changes in the outcome with the addition of new trials. Interventions that remained statistically significant within the prediction intervals were considered less likely to shift direction with the inclusion of new trials. We opted for prediction intervals over trial sequential analysis (TSA) because prediction intervals provide a range where the effect of future trials is likely to fall, enhancing our ability to generalise findings across diverse clinical settings.[11,16] This approach is especially valuable when substantial heterogeneity is present, as it allows us to anticipate variability in outcomes, whereas TSA is more focused on assessing evidence sufficiency rather than generalisability.[17,18]

The number needed to treat (NNT) was calculated using the pooled numbers in the control and intervention groups. The influence of individual trials on the primary outcome was explored by performing influence analysis to assess how each trial affected the overall result. Outlier analysis was also performed for any evident outliers. The potential small-trial effect was examined through visual inspection of the deviation from O symmetry index (Doi) plot and further evaluated using the Luis Furuya-Kanamori (LFK) asymmetry index. The Doi plot is designed to handle between-study heterogeneity better than Egger's test. High heterogeneity can distort Egger's test results, whereas the Doi plot still provides a straightforward visual and quantitative measure that helps reduce the impact of heterogeneity on the detection of asymmetry.[19]

## Results

### Literature search

A comprehensive literature search identified 154 trials from PubMed, SCOPUS, EMBASE, and CENTRAL. The study selection process is illustrated in Supplementary Figure S1. After full-text screening, three trials[20–22] were excluded as the desired parameters were not evaluated by these trials (Supplementary Table S1). Relevant data were finally available for a total of 18 RCTs, involving 2144 patients, and were included in this meta-analysis.[2–5,20,23–35] Among them, 1069 patients were in the epidural analgesia group, and 1075 were in the DPE group. There were no non-English trials that met the inclusion criteria. A visual synopsis of the literature search and trial selection is shown in the PRISMA flow diagram in Figure 1.

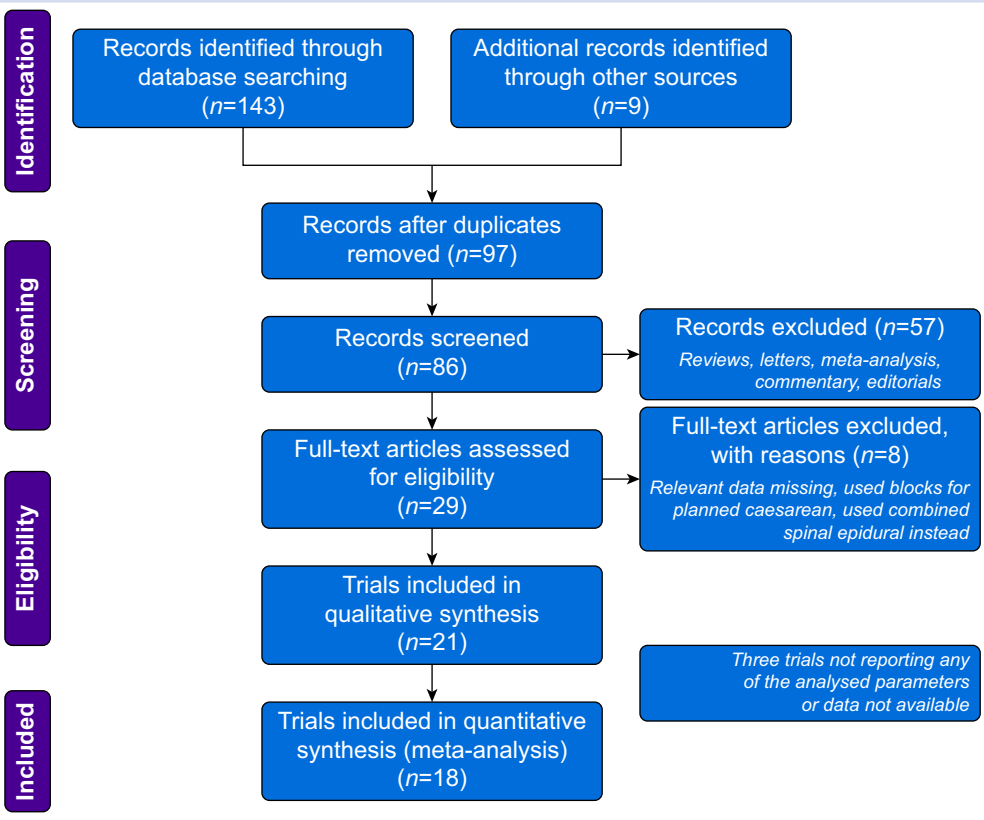


Fig 1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow diagram of trial identification and selection.

## Overview of included trials

The included trials investigated patients undergoing conventional epidural analgesia and DPE labour analgesia, excluding trials that used CSE analgesia. Three trials (Gupta and colleagues,[25] Maeda and colleagues,[27] and Thomas and colleagues[31]) lacked data for the primary outcome. Ten trials used a 25-G Whitacre spinal needle, two trials used a 26-G Whitacre needle, five trials used a 27-G Whitacre needle, and one trial used a 25-G Pencan needle (Table 1). To initiate analgesia, ropivacaine was administered in nine trials, bupivacaine in seven, and lidocaine in one, each as a bolus. Fentanyl was added as an adjuvant in eight trials, and sufentanil was used in four; five trials did not use any adjuvants. One trial did not report the type of local anaesthetic or adjuvant used (Table 1).

Eight trials did not specify the tools used for assessing analgesic adequacy. The visual analogue scale (VAS) and numeric pain rating scale were each used in five trials. Motor block assessment was omitted in six trials, whereas six trials used the Bromage score, and six used the Modified Bromage scale. One trial by Zhang and colleagues[35] recorded only the primary outcome, without secondary outcomes such as mode of delivery. The remaining 17 trials documented the mode of delivery.

Accidental dural puncture (in the epidural analgesia group) and intravascular placement of the epidural catheter were reported in only two trials (Gupta and colleagues[25] and Thomas and colleagues[31]). Unilateral block data were available in 12 trials, and sacral sparing was reported in nine. For the trial by Song and colleagues[29] we combined the DPE + continuous epidural infusion (CEI) and DPE + programmed intermittent epidural bolus (PIEB) groups, calculated the mean and SD separately, and entered the averaged values.

The characteristics of the included trials are shown in Table 1. Results for all the analysed parameters are shown in the SoF table (Table 2).

## Risk of bias assessment

The ROB assessment for each trial is shown in Figure 2. In terms of overall bias, six of the 18 RCTs were categorised as high risk (three trials did not report the primary outcome, one did not report the secondary outcomes, and protocol deviations were noted in the other two), one was assessed as having some concerns, and the remaining trials were at low risk. The most prominent source of bias across the trials was the lack of blinding of the provider performing the block. Both patients and assessors were blinded in 13 trials,[2–5 21 24 25 27 28 30 32 34 35] only parturients were blinded in one trial (Wilson and colleagues),[32] and no blinding information was available for four trials.[25,28,30,35]

Table 1 Epidural *vs* dural puncture epidural: characteristics of trials. CEI, continuous epidural infusion; CSE, combined spinal epidural; DPE, dural puncture epidural; LA, local anaesthetic; PDPH, post-dural puncture headache; PIEB, programmed intermittent epidural bolus; SD, standard deviation.

| Study no | Author, year, country | Presentation/ labour | Cervical dilation (cm) | Central neuraxial techniques | Spinal needle | Local anaesthetic/ adjuvant | Other outcomes | Comments |
|---|---|---|---|---|---|---|---|---|
| 1 | Bakhet,[23] 2021, Egypt | | ≤5 | Epidural, DPE, CSE | 25-G Whitacre | 0.1% bupivacaine, fentanyl 2 mcg/ml | Motor block, hypotension, additional top-ups | Epidural, DPE, and CSE groups, data from CSE group not taken |
| 2 | Cappiello,[24] 2008, USA | Vertex, spontaneous | <5 | Epidural, DPE | 25-G Whitacre | 0.25% bupivacaine | Motor block, hypotension, additional top-ups, sacral sparing, unilateral block | No adjuvant |
| 3 | Chau,[3] 2017, USA | Vertex, spontaneous | <5 | Epidural, DPE, CSE | 25-G Whitacre | 0.125% bupivacaine, fentanyl 2 mcg/ml | Motor block, hypotension, additional top-ups, sacral sparing, unilateral block | Epidural, DPE, and CSE groups, data from CSE group not taken, parity not given |
| 4 | Frassanito,[2] 2024, USA | Vertex | ≤5 | Epidural, DPE | 27-G Whitacre | 0.1% ropivacaine, sufentanil 0.5 mcg/ml | Motor block, hypotension, additional top-ups, sacral sparing, unilateral block | Bilateral sacral block is the primary outcome |
| 5 | Gupta,[25] 2013, USA | | | Epidural, DPE | 25-G Pencan | 0.125% bupivacaine, fentanyl 10 mcg/ml | Hypotension, additional top-ups, PDPH | No primary outcome, parity not given |
| 6 | Jadon,[26] 2021, India | Vertex, spontaneous | | Epidural, DPE | 27-G Whitacre | 0.125% bupivacaine | Motor block, hypotension, additional top-ups | No adjuvant |
| 7 | Lin,[4] 2023, China | Vertex, spontaneous | 3–5 | Epidural, DPE | 25-G Whitacre | 0.1% ropivacaine | Hypotension, additional top -ups, sacral sparing, unilateral block | No adjuvant |
| 8 | Maeda, 2024,[27] USA | Vertex, spontaneous and induced | ≤5 | Epidural, DPE | 25-G Whitacre | 0.25% bupivacaine | Hypotension, additional top-ups, unilateral block | No primary outcome, parity not given, no adjuvant |
| 9 | Puthenveettil, 2021,[28] India | Spontaneous | | Epidural, DPE | 27-G Whitacre | 0.1% ropivacaine, fentanyl 30 mcg | Motor block, hypotension, PDPH | Parity not given |
| 10 | Song, 2021,[29] China | Vertex, spontaneous | <5 | Epidural, DPE + CEI, DPE + PIEB | 25-G Whitacre | 0.1% ropivacaine, sufentanil 0.3 mcg/ml | Motor block, hypotension, additional top-ups, sacral sparing, unilateral block | Combined the DPE + CEI and DPE + PIEB into one, calculated the means/SD separately and entered the average values |
| 11 | Sravya, 2023,[30] India | Spontaneous | >2–3 | Epidural, DPE | 26-G Whitacre | Not reported | Sacral sparing, unilateral block | Nulliparous and multiparous, no LA/ adjuvant reported |
| 12 | Tan,[5] 2022, USA | Vertex, spontaneous and induced | 2–7 | Epidural, DPE | 25-G Whitacre | 0.1% ropivacaine, fentanyl 2 mcg/ml | Motor block, hypotension, additional top-ups, unilateral block | Nulliparous and multiparous |
| 13 | Thomas,[31] 2005, USA | | <6 | Epidural, DPE | 27-G Whitacre | 2% lidocaine | Sacral sparing, unilateral block | No primary outcome, parity not given, no adjuvant |
| 14 | Wang,[20] 2021, China | Spontaneous | 2–5 | Epidural, DPE | 25-G Whitacre | 0.08% ropivacaine, sufentanil 0.4 mcg/ml | Motor block, hypotension, additional top-ups, | |

*Continued*

Table 1 Continued

| Study no | Author, year, country | Presentation/ labour | Cervical dilation (cm) | Central neuraxial techniques | Spinal needle | Local anaesthetic/ adjuvant | Other outcomes | Comments |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | sacral sparing, unilateral block | |
| 15 | Wilson,[32] 2018, USA | Spontaneous | | Epidural, DPE | 26-G Whitacre | 0.125% bupivacaine, fentanyl 50 mcg | Motor block, hypotension, additional top-ups, unilateral block | Parity not given |
| 16 | Yadav,[33] 2018, India | Vertex, spontaneous | | Epidural, DPE | 27-G Whitacre | 0.2% ropivacaine, fentanyl 2 mcg/ml | | |
| 17 | Yan,[34] 2023, China | Vertex, spontaneous | <5 | Epidural + CEI, Epidural + PIEB, DPE + CEI, DPE + PIEB | 25-G Whitacre | 0.1% ropivacaine, fentanyl 2 mcg/ml | Motor block, hypotension, sacral sparing, unilateral block | For both epidural and DPE, continuous infusion and PIEB groups were combined |
| 18 | Zhang,[35] 2024, China | Vertex | | Epidural, DPE | 25-G Whitacre | 0.1% ropivacaine, sufentanil 0.5 mcg/ml | | Only primary outcome |

## Measured outcomes

### *Time to onset of block*

Fifteen trials, involving 833 patients in the epidural analgesia group and 874 in the DPE analgesia group, reported on this outcome. Using the inverse variance method (random-effects model), the analysis demonstrated that the DPE labour analgesia group had a 3.4-minute faster onset of analgesia (95% CI: 2.1–4.7) compared with the epidural analgesia group. This result was statistically significant ($P<0.01$) but revealed a high degree of heterogeneity ($I^2=97\%$) (Fig. 3). The faster onset of analgesia with DPE technique was consistent across all types of local anaesthetics and remained significant in all subgroup analyses. We calculated the prediction interval that was found to cross zero (−1.97 to 8.80). We calculated the power of this meta-analysis pooling for an alpha of 0.05 to be 95%.

### *Exploration of heterogeneity*

Regression analysis based on the type of local anaesthetic showed an $R^2$ of 0, indicating that none of the observed heterogeneity was attributable to differences in anaesthetics. To further explore the sources of heterogeneity for the outcome of time to onset of analgesia between epidural analgesia and DPE technique, several sensitivity analyses were conducted.

First, a Baujat plot was generated (Supplementary Fig. S1), which revealed that one trial[15] contributed the most towards heterogeneity and another trial[11] contributed the most to the final effect size. This approach allowed us to visually pinpoint trials that were influential in distorting the overall results by contributing to the observed heterogeneity.

Next, we performed an influence analysis (Supplementary Fig. S2). This analysis revealed how individual trials influenced the overall results by evaluating the change in the pooled effect size when each trial was added sequentially to the pooled result. None of the trials included were found to be outliers or had high leverage that may bias the results.

We performed a leave-one-trial-out analysis, generating forest plots for each trial exclusion to assess its impact on effect size and heterogeneity and identifying trials that significantly influenced pooled estimates (Supplementary Figs S3 and S4). No single trial disproportionately influenced heterogeneity or the effect size, and cumulative variations across trials accounted for up to 97% of the heterogeneity. Lastly, we assessed publication bias using a Doi plot and calculated the LFK index as 0.47, indicating no asymmetry. This suggests that there may be minimal risk of publication bias in the primary outcome (Supplementary Fig. S5).

### *Unilateral block*

Data from 12 trials, involving 881 patients in the DPE analgesia group and 861 in the epidural analgesia group, revealed that DPE analgesia reduced unilateral block by nearly 97%. The inverse variance analysis yielded an OR of 2.02 (95% CI: 1.14–3.59), with significant heterogeneity ($I^2=66\%$, $P<0.01$). The calculated NNT was approximately 13, indicating that, on average, treating 13 patients with DPE analgesia instead of a traditional epidural analgesia would prevent one additional case of unilateral block. The random-effects model showed that the DPE technique was associated with fewer unilateral blocks for ropivacaine, and this benefit was not demonstrable for the bupivacaine subgroup. (Supplementary Fig. S6).

**Table 2** Summary of findings (SoF) for the pairwise meta-analysis, conducted according to GRADE (Grading of Recommendations Assessment, Development, and Evaluations) guidelines. The table presents the quality of evidence for each outcome, categorised into high, moderate, low, or very low based on factors such as risk of bias, heterogeneity, and publication bias. The anticipated effects are displayed, along with the number of participants and trials included in the analysis. DPE, dural puncture epidural; GRADE, Grading of Recommendations Assessment, Development, and Evaluation; NA, not applicable; OR, odds ratio.

| Outcomes | Anticipated absolute effects of intervention | | Heterogeneity ($I^2$), % | Relative effect or mean difference | Prediction interval | Number of participants (studies) | Certainty of evidence (GRADE) | What happens |
|---|---|---|---|---|---|---|---|---|
| | With epidural analgesia (control) | With DPE analgesia (intervention) | | | | | | |
| **Onset of analgesia** (mean duration in minutes) | 14.1 min | 10.7 min | 97 | 3.4 (2.10–4.7) min 24.03% reduction | −1.97 to 8.80 | 1707 (15) | ⊕⊕⊖⊖ Low | DPE quickens the onset of analgesia |
| **Unilateral block** (number of patients) | 1/100 | 9.8/100 | 66 | OR 2.02 (1.14–3.59) 45.05% reduction | 0.32–12.80 | 1742 (12) | ⊕⊕⊖⊖ Low | Unilateral block is less likely with DPE |
| **Sacral sparing** (number of patients) | 34.61/100 | 15.95/100 | 80 | OR 2.79 (1.43–5.55) 53.9% reduction | 0.31–24.91 | 1435 (9) | ⊕⊕⊖⊖ Low | Sacral sparing is less likely with DPE |
| **Motor block** (number of patients) | 10.81/100 | 5.85/100 | 0 | OR 1.95 (1.15–3.33) 45.9% reduction | 1.03–3.72 | 1435 (12) | ⊕⊕⊕⊕ High | Motor block is less likely with DPE |
| **Adequate analgesia after initiation** (number of patients) | 78.30/100 | 84.92/100 | 0 | OR 0.50 (0.38–0.67) 15.1% increase | 0.35–0.72 | 1372 (10) | ⊕⊕⊕⊕ High | Analgesia quality is likely better with DPE |
| Outcomes that failed to achieve statistical significance | | | | | | | | |
| **Need for additional boluses** (number of patients) | 39.05/100 | 32.99/100 | 61.70 | OR 1.30 (0.84–2.01) 15.5% reduction | NA | 1739 (12) | ⊖⊖⊖⊖ Very low | $P$=0.24 |
| **Caesarean section rate** (number of patients) | 15.03/100 | 14.42/100 | 0 | OR 1.05 (0.82–1.35) 4.1% reduction | NA | 2084 (17) | ⊖⊖⊖⊖ Very low | $P$=0.70 |
| **Operative vaginal delivery rate** (number of patients) | 6.85/100 | 7.71/100 | 0 | OR 0.88 (0.62–1.27) 12.6% increase | NA | 1912 (15) | ⊖⊖⊖⊖ Very low | $P$=0.50 |
| **Hypotension rate** (number of patients) | 6.5/100 | 7.02/100 | 0 | OR 0.93 (0.63–1.37) 7.0% increase | NA | 1894 (13) | ⊖⊖⊖⊖ Very low | $P$=0.71 |
| **Catheter replacement rate** (number of patients) | 5.14/100 | 3.15/100 | 0 | OR 1.67 (0.89–3.02) 38.7% reduction | NA | 1226 (7) | ⊖⊖⊖⊖ Very Low | $P$=0.11 |

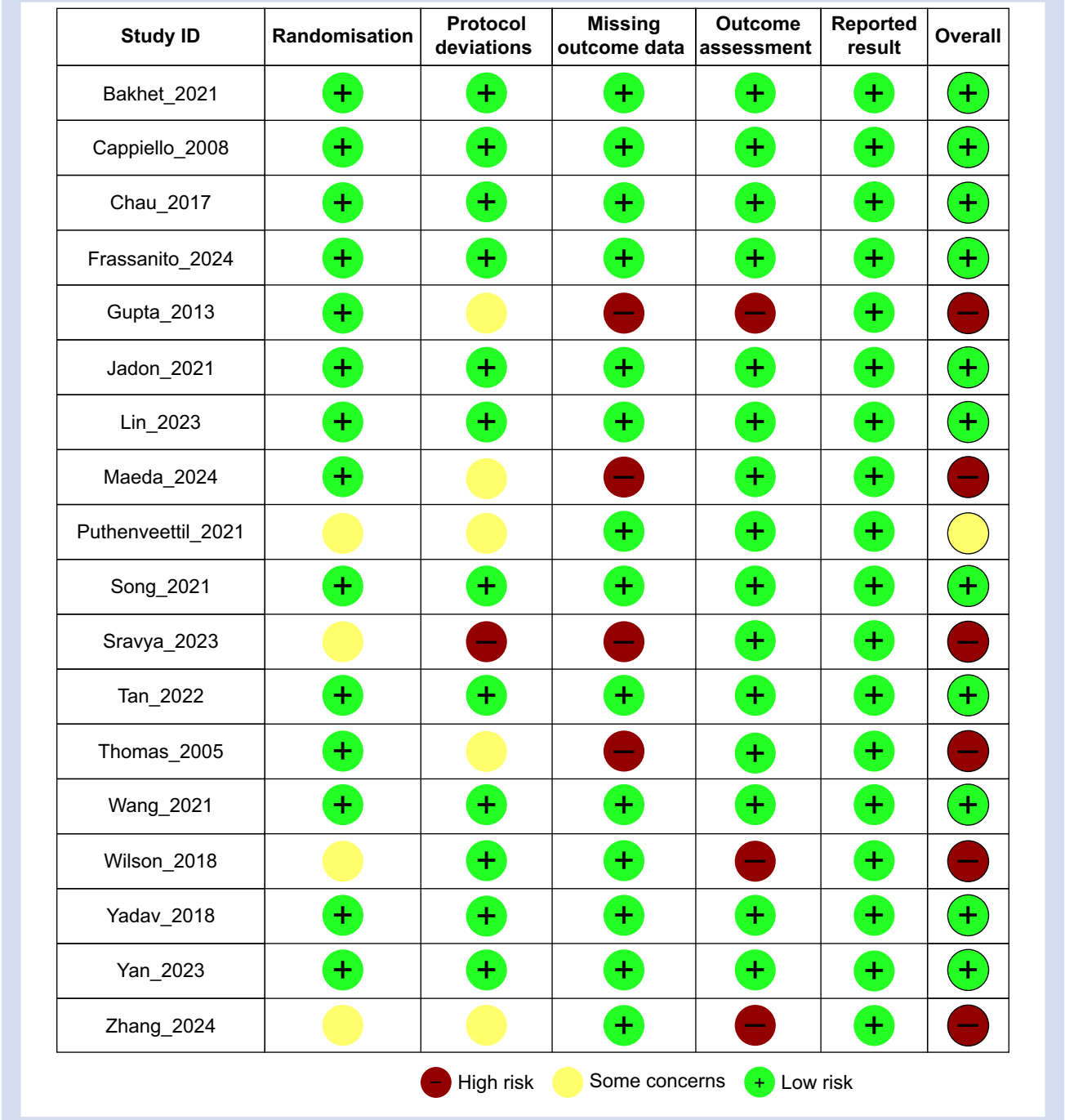


Fig 2. Risk of bias (ROB) for time to onset. This plot displays the ROB assessment for each trial included in the meta-analysis, evaluating domains such as selection, performance, detection, attrition, and reporting biases. Each coloured bar represents the level of bias, low (green), unclear (yellow), or high (red), as determined through standardised criteria. The plot provides an overview of methodological quality across trials, highlighting potential biases that may influence the overall findings. This visualisation aids in understanding how trial quality may affect the robustness of the meta-analysis results.

To explore heterogeneity, we conducted a leave-one-trial-out analysis, generating separate forest plots for each iteration and sequential trial exclusion to determine the impact on effect size (Supplementary Fig. S7) and heterogeneity (Supplementary Fig. S8). Although no single trial disproportionately impacted heterogeneity or the effect size, the combined variations across trials contributed to up to 66% of the heterogeneity.

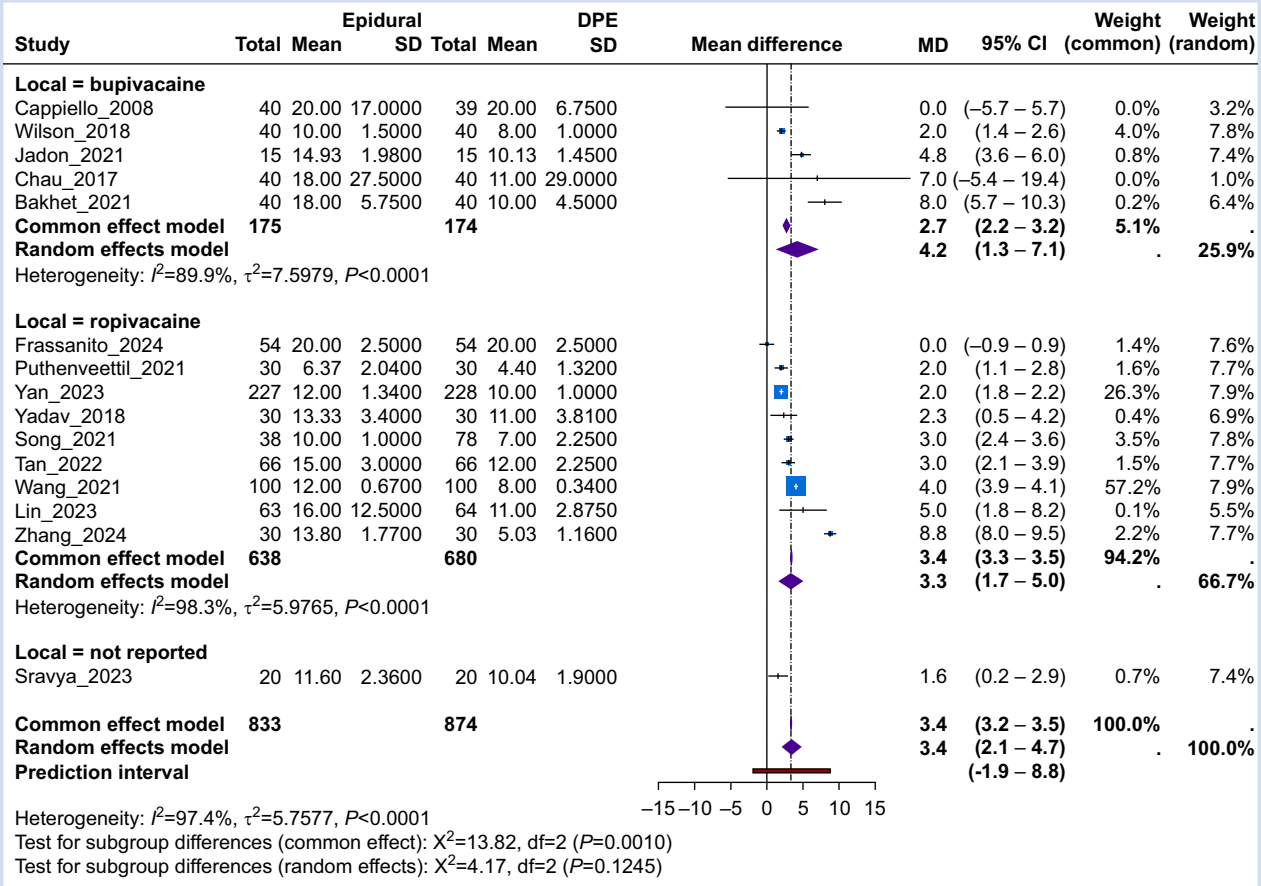


Fig 3. This forest plot compares the onset of analgesia between epidural analgesia and DPE analgesia techniques, with results presented for both common-effects and random-effects models using the inverse variance method. Trials are grouped by type of local anaesthetic used, with subgroup analyses displayed. Each horizontal line represents the 95% confidence interval (CI) for an individual trial's effect size, with a diamond indicating the pooled effect size for each model. The red bar at the bottom shows the prediction interval (which crosses zero), reflecting expected variation with future trials. CI, confidence interval; DPE, dural puncture epidural; MD, mean difference.

### *Sacral sparing*

The implementation of DPE analgesia was associated with a significant reduction in the incidence of sacral sparing. An analysis of data from nine trials, which included 730 patients in the DPE group and 705 in the epidural analgesia group, revealed that performing the DPE technique was associated with an OR of 2.79 (95% CI: 1.43–5.44) for avoiding sacral sparing, indicating a notable improvement compared with epidural analgesia. The heterogeneity observed in this analysis was considerable ($I^2$=80%, $P$<0.01). The estimated NNT was 6.25, suggesting that for every six patients who received DPE analgesia instead of epidural analgesia, approximately one patient would have better sacral dermatome coverage (Supplementary Fig. S9).

We conducted a leave-one-trial-out analysis to identify contributions to heterogeneity and overall effect size, visualised in Supplementary Figures S10 and S11, respectively. Although no single trial disproportionately influenced heterogeneity or the effect size, cumulative variations across trials accounted for up to 80% of the heterogeneity.

### *Motor block*

The use of DPE analgesia was associated with a significant reduction in the incidence of motor block. An analysis of 12 trials, including 775 patients in the DPE analgesia group and 740 in the traditional epidural analgesia group, yielded an OR of 1.95 (95% CI: 1.15–3.33) in favour of DPE analgesia. The heterogeneity was negligible ($I^2$=0%, $P$<0.01), indicating consistent findings across the trials. Furthermore, the 95% prediction interval (1.03–3.72) suggests that future trials are unlikely to change the direction of the effect (Supplementary Fig. S12).

The estimated NNT was approximately 34, suggesting that treating 34 patients with DPE analgesia instead of a traditional epidural analgesia would prevent one additional case of motor block. This analysis also indicates that epidural analgesia is associated with a 95% higher likelihood of motor block compared with DPE analgesia.

In subgroup analyses, motor block was statistically insignificant in the ropivacaine group but was significant in the bupivacaine group, with the overall value remaining statistically significant.

### *Reported adequate analgesia*

Data from 10 trials, including 704 patients in the DPE analgesia group and 668 in the traditional epidural analgesia group, were pooled to assess the likelihood of achieving adequate analgesia. The analysis resulted in an OR of 0.50 (95% CI: 0.38–0.67), favouring DPE analgesia. Heterogeneity was minimal ($I^2$=0%, $P$<0.01), and the 95% prediction interval (0.35–0.72) suggests that future trials are unlikely to alter the direction of the effect (Supplementary Fig. S13).

The NNT was approximately nine, indicating that for every nine patients treated with DPE analgesia instead of traditional epidural analgesia, one additional patient would achieve adequate analgesia. The DPE technique was found to be 50% more effective in providing adequate pain relief compared with traditional epidural analgesia. Furthermore, this result remained statistically significant across both the bupivacaine and ropivacaine subgroups.

### *Need for additional top-ups*

Twelve trials, involving 717 patients in the epidural analgesia group and 722 in the DPE analgesia group, assessed the need for additional top-ups. The meta-analysis yielded a Mantel–Haenszel (MH) OR of 1.30 (95% CI: 0.84–2.01), with a $P$-value of 0.24 and $I^2$ of 61.70% (Supplementary Fig. S14).

### *Caesarean section rate*

Seventeen trials pooled data from 1039 patients in the epidural analgesia group and 1045 in the DPE analgesia group. The analysis revealed comparable risk for Caesarean delivery with either DPE or epidural analgesia, with an MH OR of 1.05 (95% CI: 0.82–1.35, $P$=0.70, $I^2$=0%) using a random-effects model. No statistically significant differences were observed across different local anaesthetic subgroups (Supplementary Fig. S15).

### *Operative vaginal delivery*

Fifteen trials, including 946 patients in the epidural group and 966 in the DPE analgesia group, reported on the rate of operative vaginal deliveries. The MH OR for epidural *vs* DPE analgesia was (0.88, 95% CI: 0.62–1.27), and was not statistically significant ($P$=0.50, $I^2$=0%). There was no significant difference across local anaesthetic types (Supplementary Fig. S16).

### *Hypotension rate*

Thirteen trials reported hypotension outcomes for 944 patients receiving epidural analgesia and 950 receiving DPE analgesia. This finding was not statistically significant, with an MH OR of 0.93 (95% CI: 0.63–1.37, $P$=0.71, $I^2$=0%) using a random-effects model. No significant differences were found in the subgroups based on different local anaesthetics (Supplementary Fig. S17).

### *Catheter replacement rate*

This outcome was reported in seven trials, which included 623 patients in the epidural analgesia group and 603 in the DPE analgesia group. The comparative odds of need for catheter replacement in the epidural analgesia group *vs* DPE analgesia group (MH OR: 1.67, 95% CI: 0.89–3.02) did not reach statistical significance ($P$=0.11, $I^2$=0%). The results were similarly nonsignificant when analysed by local anaesthetic subgroup (Supplementary Fig. S18).

## Discussion

Our meta-analysis offers a comprehensive evaluation of both the DPE analgesia and traditional epidural analgesia techniques for labour, synthesising data from a larger and more diverse set of trials than previous analyses. Advanced statistical techniques were used to analyse this updated dataset, providing a confirmation of the advantages of the DPE technique in terms of the onset of analgesia, frequency of motor block, and sacral sparing. These outcomes have been widely discussed in the literature. Rapid and sustained pain relief during labour is important for maternal satisfaction. Additionally, motor block may negatively impact labour duration (prolonged second stage)[36] or can increase the rate of operative vaginal delivery.[37]

Earlier individual trials proposed that the DPE analgesia might provide benefits over traditional epidural analgesia. However, these trials were limited by small sample sizes and variability across study designs, which often left the clinical community with mixed conclusions. Subsequently, a systematic review by Heesen and colleagues[6] suggested that DPE labour analgesia may lead to faster onset and better sacral coverage. However, this study did not provide a quantitative synthesis of the data, limiting the ability to assess the statistical significance of these outcomes. A recent meta-analysis by Yin and colleagues[7] reported a faster onset of analgesia with the DPE technique but did not specify precise mean time differences in the onset of analgesia. They primarily focused on comparative pain scores. These pain scores were reported across different times during labour, thus questioning the validity of the pooling spread. Another systematic review conducted by De Haes and colleagues[38] had several limitations. Their analysis missed multiple trials available at the time of publishing. The researchers examined a limited number of parameters and did not attempt to explore heterogeneity. Because of these multiple missed trials, they were unable to draw any conclusions. Additionally, none of the analysed parameters reached statistical significance, which could be attributed to the overall small number of trials included. Additionally, no attempts were made to evaluate the findings with available statistical tools like TSA or imputing prediction intervals.

Our large and statistically rigorous meta-analysis consolidates the available body of evidence for these outcomes, providing adequate power to analyse the theoretical benefits of DPE analgesia across various settings and patient populations. Our results provide valuable insights into how the DPE technique can enhance the patient experience during labour, suggesting that DPE analgesia may be preferred over traditional epidural analgesia for effective neuraxial labour pain relief. These findings include a small but statistically significant reduction in the time of onset of analgesia. Furthermore, we observed a significant reduction in the incidence of motor block associated with DPE, with an OR of 1.95 indicating that traditional epidural analgesia is associated with a 95% higher likelihood of motor block than the DPE. This advantage highlights the potential for DPE analgesia to reduce operative vaginal deliveries. Additionally, it is plausible that reduced motor block may be associated with a shorter duration of the second stage of labour. Although our efforts to pool data on labour duration were unsuccessful because of

inconsistent documentation across trials, future studies should investigate this variable in light of our findings. Conversely, Yin and colleagues[7] suggested that the need for additional top-ups was reduced with the DPE technique, our results differed. This discrepancy emphasises the importance of robust analyses, including the use of prediction intervals, to guard against false-positive results and ensure reliable conclusions. Similarly, a 2021 meta-analysis by De Haes and colleagues[38] omitted several trials and suffered from similar statistical limitations.

Our meta-analysis is unique in that we were able to subdivide and analyse the results according to local anaesthetic, facilitating indirect comparison between bupivacaine and ropivacaine. Our analysis revealed comparable outcomes for both local anaesthetics when used at clinical concentrations, suggesting that the selection of either anaesthetic can be reasonably determined by institutional availability and cost.

We leveraged the inverse variance method, which provides several advantages in handling the diverse datasets of a meta-analysis. By weighting trials based on the precision of their estimates, this method minimises the influence of trials with less reliable data and maximises the impact of trials with larger sample sizes or narrower CIs. This statistical approach ensures that our results reflect a more precise and reliable effect size, enhancing the confidence of our conclusions across key outcomes including analgesic onset and motor block incidence.

From a clinical perspective, some of the outcomes identified have significant implications for patient satisfaction. The quicker onset of analgesia with DPE enhances patient comfort and may be advantageous in clinical settings requiring prompt pain management where CSE techniques are not routinely practiced or feasible. Our findings on sacral sparing further support DPE analgesia's role in offering a more complete sensory block, enhancing overall analgesic efficacy.

In terms of secondary outcomes, such as operative and Caesarean delivery rates and the need for additional top-ups, our results align with the mixed findings of prior individual trials and systematic reviews. Statistical significance was not reached across these multiple outcomes, suggesting that more trials may be needed to draw conclusions regarding the superiority (or equivalence) of one technique over another. By using prediction intervals, our study provides a framework to understand how future trials might impact these conclusions, providing guidance on where best to dedicate resources for future investigations.

Although this analysis was not designed to compare CSE analgesia *vs* DPE analgesia or epidural analgesia, we recognise that the benefits of the DPE technique reported here may also be observed with the CSE technique. The shared mechanism of dural puncture with a spinal needle to confirm epidural access and facilitate intrathecal translocation of epidural drug logically supports the use of either technique to achieve timely and effective labour analgesia. Avoidance of hypotension and potentially compromised uteroplacental blood flow, however, remains an important clinical goal during the provision of neuraxial analgesia, and the omission of a spinal dose with the DPE technique likely reduces this risk. Further studies comparing the CSE and DPE techniques for patient centred outcomes are warranted.

## Limitations

Despite the strengths of our meta-analysis, several limitations should be acknowledged. One of the potential limitations of our study is the clinical relevance of the observed 2–3-min difference in the onset of analgesia with the DPE technique. Although this difference may not seem significant when considering the overall duration of labour, it is important to recognise that faster onset could contribute to an overall improved patient experience, particularly when viewed alongside other benefits observed in secondary outcomes. It may still offer an advantage in clinical scenarios where rapid pain relief is crucial. Furthermore, without directly comparing techniques, it is difficult to predict *a priori* whether a clinically valuable difference exists. Our findings suggest that patient satisfaction with DPE analgesia is unlikely to improve substantially if onset of analgesia is the only parameter considered.

The included trials exhibited a high degree of heterogeneity, which may stem from variations in dosing practices, differences in the concentration of local anaesthetics used, spinal needle gauge, opioid dose/concentration, analgesia maintenance technique, and inconsistent timing of epidural analgesia or DPE analgesia administration. Although some trials performed these blocks early in labour, others lacked a standardised cervical dilation threshold, potentially affecting the outcomes measured. Additionally, the assessment of motor and sensory block and the adequacy of analgesia varied across trials, requiring us to rely on the definitions provided by each trial. We were also unable to analyse the impact of different concentrations of local anaesthetics, which may influence the comparative effectiveness of DPE analgesia *vs* traditional epidural analgesia techniques.

The concentration of local anaesthetics is likely to influence many of the parameters we analysed, including the primary and secondary outcomes. This is an important consideration, as there was notable variation in the concentrations of local anaesthetics used across the included studies (Table 1). For bupivacaine, the concentrations ranged from 0.1% to 0.25%, with the latter observed in only two trials. Among the five trials contributing to the primary outcome, four used 0.125% bupivacaine, and one used 0.25% (Fig. 3). For ropivacaine, nine trials contributed to the primary outcome (Fig. 3), with concentrations ranging from 0.08% (one trial) to 0.2% (one trial), and with seven trials using 0.1% (Table 1). To address the potential influence of higher concentrations, we performed a sensitivity analysis excluding trials that used 0.25% bupivacaine and 0.2% ropivacaine. This analysis (Supplementary Fig. S19a–e) showed minimal changes in the results, apart from the expected reductions in overall sample size.

In hindsight, subgrouping based on local anaesthetic concentration would have been more clinically relevant, as bupivacaine and ropivacaine appear to have minimal impact on the outcomes analysed. Indeed, our subgroup analysis also demonstrates that most parameters did not differ significantly between these two agents. However, as our registered protocol specified the primary analysis based on the type of local anaesthetic, we adhered to this pre-specified plan. We attempted to include a secondary analysis based on local anaesthetic concentration, but drawing strong conclusions was challenging. Variations in dosing regimens, maintenance techniques, and other procedural factors across trials made it difficult to isolate the impact of concentration differences. These limitations underscore the challenges in teasing out subtle differences, if they exist, and highlight the need for more standardised approaches in future studies.

An important consideration in the DPE technique is the gauge of the spinal needle used, as it may influence the clinical outcomes. In this analysis, ~60% of the included trials (11/18) used a 25-G Whitacre needle (Table 1), and sensitivity analysis was performed based on spinal needle gauge for the statistically significant outcomes. Given the observed variation in needle gauge across studies, subgrouping by needle size did not reveal any substantial differences in the measured outcomes. It is important to note that comparisons between different needle types were not directly possible within the scope of this pairwise meta-analysis. Instead, indirect comparisons were made using epidural analgesia as the common comparator. Supplementary Fig. 20a–e with the subgroup analysis based on needle gauge has been provided for transparency. However, interpretations of these results should be made with caution, considering the limitations of pairwise meta-analysis and the lack of direct comparison between needle types.

Finally, although we aimed to investigate other outcomes, such as the incidence of PDPH, incidence of failed analgesia, and accidental dural puncture rates, these events were inconsistently reported across trials, making pooling for meta-analysis infeasible.

### Conclusions

This meta-analysis highlights the significant benefits of the DPE technique compared with traditional labour epidural analgesia. Notably, the DPE analgesia technique is associated with slightly faster onset of analgesia (compared with epidural analgesia alone), a reduction in motor block, and decreased incidence of unilateral block and sacral sparing, all of which were statistically significant. The clinical relevance of the faster onset of analgesia with the DPE technique may be modest; however, when considered alongside other benefits observed in secondary outcomes, it strengthens the case for its use over traditional epidural analgesia.

It is worth noting that interpretation of these results should be approached cautiously given the high heterogeneity observed across several outcomes, including time to onset of analgesia and presence of unilateral block. These variations may reflect differences in clinical practice and dosing among trials.

## Authors' contributions

Statistical analysis: PMS
Manuscript preparation: PMS, DTM, ADB, AB, MK, PY, MK
Risk of bias assessment ADB, AB, MK
Data extraction: AB, MK, MK
Concept design: MK, PMS

## Declaration of interest

The authors declare that they have no conflicts of interest.

## Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work, the author(s) used ChatGPT to check/improve language. After using this tool/service, the author(s) reviewed and edited the content as needed and take(s) full responsibility for the content of the publication.

## Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.bja.2025.01.033.

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