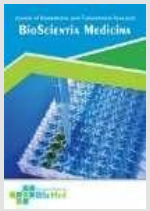
eISSN (Online): 2598-0580



Bioscientia Medicina: Journal of Biomedicine & Translational Research

Journal Homepage: www.bioscmed.com

Programmed Intermittent Epidural Bolus (PIEB) Versus Patient-Controlled Epidural Analgesia (PCEA) with Continuous Basal Infusion for Labor Analgesia: A Meta-Analysis

Nopian Hidayat[1*], Novita Anggraeni[1], Ricko Yorinda Putra[1]

[1]Department of Anesthesiology and Intensive Care, Faculty of Medicine, Universitas Riau, Pekanbaru, Indonesia

ARTICLE INFO

Keywords:
Continuous basal infusion
Labor analgesia
Obstetric anesthesia
Patient-controlled epidural analgesia
Programmed intermittent epidural bolus

***Corresponding author:**
Nopian Hidayat

E-mail address:
nopian.h@gmail.com

All authors have reviewed and approved the final version of the manuscript.

https://doi.org/10.37275/bsm.v9i6.1311

A B S T R A C T

Background: Maintaining effective labor epidural analgesia while optimizing maternal satisfaction and minimizing drug consumption remains a key objective in obstetric anesthesia. Programmed intermittent epidural bolus (PIEB) techniques have emerged as an alternative to traditional continuous epidural infusion (CEI) combined with patient-controlled epidural analgesia (PCEA). This meta-analysis aimed to compare the efficacy, local anesthetic (LA) consumption, and maternal satisfaction between PIEB regimens (typically combined with PCEA for rescue) and PCEA regimens supplemented with a continuous basal infusion (PCEA+Basal). **Methods:** A systematic literature search was conducted for PubMed, EMBASE, and the Cochrane Library for randomized controlled trials (RCTs) published between January 2013 and December 2024 comparing PIEB (+/- PCEA) with PCEA+Basal for labor analgesia. Primary outcomes were hourly LA consumption, maternal satisfaction (rated as high/excellent), and need for clinician rescue analgesia (breakthrough pain). Secondary outcomes included pain scores (Visual Analog Scale - VAS), mode of delivery, duration of labor stages, motor blockade incidence, and neonatal outcomes (Apgar scores). Data were extracted from suitable studies identified through the search. A random-effects model was used for meta-analysis using RevMan software. Mean Differences (MD) or Odds Ratios (OR) with 95% Confidence Intervals (CI) were calculated. Heterogeneity was assessed using the I^2 statistic. **Results:** Five studies involving a total of 1158 parturients met the inclusion criteria. The pooled analysis indicated that PIEB regimens were associated with a trend towards lower hourly LA consumption compared to PCEA+Basal (MD: -1.2 mL/hour; 95% CI: -2.5 to 0.1; P=0.07; I^2=78%), although heterogeneity was high. Maternal satisfaction rated as 'high' or 'excellent' was significantly more frequent in the PIEB group (OR: 1.85; 95% CI: 1.20 to 2.85; P=0.005; I^2=35%). The need for clinician rescue analgesia was numerically lower with PIEB, but the difference did not reach statistical significance (OR: 0.70; 95% CI: 0.45 to 1.10; P=0.12; I^2=45%). No significant differences were noted in VAS pain scores during established labor, mode of delivery, or Apgar scores. Incidence of motor block appeared potentially lower with PIEB regimens. **Conclusion:** Based on this meta-analysis, PIEB regimens appear promising for labor analgesia, potentially offering comparable efficacy to PCEA+Basal while possibly reducing local anesthetic consumption and enhancing maternal satisfaction. However, significant heterogeneity was observed for some outcomes. High-quality, large-scale RCTs directly comparing optimized PIEB+PCEA protocols with PCEA+Basal infusion are crucial to definitively establish the relative benefits and risks of these techniques.

1. Introduction

Labor pain is frequently characterized as one of the most intense forms of discomfort a woman can experience. The effective management of this pain is of paramount importance, extending beyond the immediate concern of maternal comfort and psychological well-being to potentially exert influence on both maternal and neonatal outcomes. Among the

various methods employed for labor analgesia, neuraxial techniques, and particularly lumbar epidural analgesia, have established themselves as the gold standard for achieving effective pain relief during labor and delivery. The widespread adoption of epidural analgesia is rooted in its capacity to provide profound sensory blockade while minimizing systemic medication effects on both the mother and the fetus, provided it is administered correctly. The methodologies for maintaining epidural labor analgesia have undergone significant evolution over the past few decades. Early techniques primarily relied on intermittent bolus administration by clinicians. This approach, however, often resulted in fluctuations in the level of analgesia experienced by the parturient and placed considerable demands on provider attention and time. The introduction of continuous epidural infusion (CEI) represented a step forward, offering a more stable level of analgesia. Nevertheless, CEI was associated with higher local anesthetic (LA) consumption, an increased incidence of motor blockade, the potential for a prolonged second stage of labor, and, according to some earlier studies, a higher rate of instrumental deliveries.[1-3]

The development of patient-controlled epidural analgesia (PCEA) signified a substantial advancement in the field. PCEA empowers parturients by enabling them to self-administer small boluses of LA solution in response to their individual perception of pain intensity. When used alone, PCEA has demonstrated the potential to reduce total LA consumption and decrease the occurrence of motor block when compared to CEI. However, the use of PCEA as a sole analgesic technique can sometimes lead to inconsistencies in the level of analgesia, characterized by periods of inadequate pain relief between patient-initiated boluses, a phenomenon described as the "peaks and valleys" effect. To mitigate this, a background infusion is often required to establish and maintain a more consistent baseline level of comfort. Consequently, the combination of PCEA with a continuous basal infusion (PCEA+Basal) has become a widely adopted standard practice in many institutions, seeking to achieve a balance between patient control and a stable analgesic foundation. While this combination has proven effective, it is not without its potential drawbacks. The continuous infusion component still carries the risks associated with dose accumulation and the potential for motor block.[4,5]

In more recent years, programmed intermittent epidural bolus (PIEB) techniques have garnered considerable attention and increasing popularity within the field of obstetric anesthesia. PIEB involves the automated delivery of scheduled, larger-volume boluses of LA solution at predetermined intervals, facilitated by an infusion pump. The underlying hypothesis is that this method achieves a more effective dermatomal spread of the local anesthetic within the epidural space compared to the slower, continuous administration characteristic of CEI. This improved spread potentially translates to more effective sensory blockade, even with a lower total drug dosage. Furthermore, the intermittent nature of bolus delivery, in contrast to the continuous administration of CEI, may contribute to a reduction in the incidence of tachyphylaxis and motor blockade. In contemporary practice, most PIEB protocols are implemented in conjunction with PCEA availability, a combined approach known as PIEB+PCEA. This strategy aims to integrate the benefits of automated baseline analgesia with the advantage of patient empowerment, allowing parturients to supplement the scheduled boluses with on-demand boluses to manage breakthrough pain.[6,7]

Several meta-analyses have been conducted to compare PIEB+PCEA regimens with CEI+PCEA regimens. The findings of these analyses have generally indicated advantages associated with PIEB+PCEA, including a reduction in LA consumption, a decrease in motor block, a lower requirement for manual rescue boluses, and maternal satisfaction that is either improved or comparable. However, it is important to note that there is a relative scarcity of direct comparisons between PIEB (with or without PCEA) and the alternative strategy of PCEA combined with a continuous basal infusion

(PCEA+Basal). While both PCEA+Basal and PIEB aim to provide a baseline level of analgesia, their pharmacokinetic and pharmacodynamic profiles diverge significantly due to the difference in administration – continuous versus intermittent. A recent retrospective study that compared PIEB+PCEA with PCEA+Basal reported comparable levels of maternal satisfaction. However, the study also suggested potential differences in delivery modes and neonatal scores, although these results were not consistent. Therefore, a more comprehensive understanding of the relative merits of these two advanced maintenance strategies (PIEB plus PCEA and PCEA plus basal), is essential for the optimization of labor analgesia protocols.[8-10] In light of these considerations, the primary objective of this systematic review and meta-analysis was to compare the efficacy, as measured by pain scores and the need for rescue analgesia, total hourly local anesthetic consumption, and maternal satisfaction associated with PIEB-based regimens and PCEA plus basal regimens for the maintenance of epidural labor analgesia. The secondary objectives of this analysis included a comparison of the effects of these regimens on motor blockade, the duration of labor, the mode of delivery, and neonatal outcomes.

2. Methods

This systematic review and meta-analysis was conducted adhering to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines, ensuring a transparent and rigorous approach to the synthesis of evidence. The inclusion of studies in this meta-analysis was determined by a set of predefined eligibility criteria. Studies were considered eligible if they employed a randomized controlled trial (RCT) design. Participants in these trials had to be parturients undergoing vaginal delivery who had requested and received epidural analgesia for the management of labor pain. The studies of interest involved a comparison between a PIEB-based regimen and a PCEA regimen combined with a continuous background basal infusion (PCEA plus basal). A PIEB-based regimen was defined as PIEB alone or PIEB combined with PCEA. The comparator group consisted of PCEA combined with a continuous basal infusion. Studies that compared PIEB only versus PCEA only (without basal), or PIEB versus CEI (without PCEA) were excluded from the analysis. Additionally, studies comparing different PIEB settings without a PCEA plus basal comparator were also excluded. To be included, studies had to report on at least one of the primary outcomes, which were defined as hourly LA consumption (mL/hour or mg/hour), maternal satisfaction (assessed using a numerical rating scale, Likert scale, or a categorical rating such as 'excellent' or 'high'), or the need for clinician-administered rescue analgesia or top-ups for breakthrough pain. The secondary outcomes of interest encompassed VAS pain scores during established labor, the incidence and severity of motor blockade (evaluated using scales like the Bromage scale), the duration of the first and second stages of labor, the mode of delivery (including spontaneous vaginal delivery, instrumental delivery, and Cesarean section), and neonatal outcomes, specifically Apgar scores and umbilical artery pH. The meta-analysis was restricted to studies published in the English language, spanning from January 1st, 2013, to December 31st, 2024.

A comprehensive and systematic literature search was conducted to identify relevant studies. The search encompassed the following electronic databases: PubMed, EMBASE, and the Cochrane Central Register of Controlled Trials (CENTRAL). The search strategy employed a combination of Medical Subject Headings (MeSH) terms and text words. These terms were related to the intervention of interest, including "programmed intermittent epidural bolus," "automated intermittent bolus," "PCEA," "patient controlled epidural analgesia," "basal infusion," and "continuous epidural infusion." Terms related to the population and setting, such as "labor analgesia," "obstetric anesthesia," and "childbirth," were also used. An example of the search string used in PubMed is as follows: (("programmed intermittent epidural

bolus"[Title/Abstract] OR "PIEB"[Title/Abstract]) AND ("patient controlled epidural analgesia"[Title/Abstract] OR "PCEA"[Title/Abstract]) AND ("basal infusion"[Title/Abstract] OR "continuous infusion"[Title/Abstract]) AND ("labor analgesia"[MeSH Terms] OR "labour analgesia"[Title/Abstract] OR "childbirth"[Title/Abstract])) AND (randomized controlled trial[Publication Type] OR randomized[Title/Abstract]). To further ensure the comprehensiveness of the search, the reference lists of retrieved articles and relevant systematic reviews were also manually searched for potentially eligible studies.

The process of study selection involved a two-stage screening process. In the first stage, two reviewers independently screened the titles and abstracts of the studies identified through the search strategy. This screening was conducted against the predefined eligibility criteria to identify potentially relevant articles. In the second stage, the full texts of articles deemed potentially relevant during the initial screening were retrieved. These full-text articles were then independently assessed by the two reviewers to determine their final eligibility for inclusion in the meta-analysis. Any disagreements that arose between the reviewers regarding the inclusion of studies were resolved through discussion and consensus. In cases where consensus could not be reached, a third reviewer was consulted to arbitrate and make a final decision on the study's inclusion.

To ensure the accuracy and completeness of the data used in the meta-analysis, a standardized data extraction form was utilized. Two independent reviewers used this form to extract relevant information from each of the included studies. The data extracted included a variety of study characteristics, such as the first author's name, the year of publication, the country where the study was conducted, the study design, and the sample size of each group. Participant characteristics, including parity and baseline cervical dilation, were also extracted. Detailed information regarding the epidural technique employed in each study was collected. This included the type and concentration of local anesthetic used, the type and dose of any opioid adjuvant, and specific details of the PIEB settings, such as volume, interval, and flow rate. For studies involving PCEA, the bolus dose, lockout interval, and basal rate were extracted. Outcome data for both primary and secondary outcomes were extracted. For continuous outcomes, such as LA consumption, VAS scores, and labor duration, the mean and standard deviation (SD) for each group were extracted. For dichotomous outcomes, such as high satisfaction rate, need for rescue analgesia, motor block incidence, and mode of delivery, the number of events and the total number of participants in each group were extracted. Any discrepancies that arose during the data extraction process were resolved through discussion and consensus between the reviewers. In cases where consensus could not be reached, a third-party review was employed to adjudicate and resolve the discrepancies.

To ensure the completeness of the data used in the meta-analysis, attempts were made to obtain missing data. The authors of the included studies were contacted if data required for the meta-analysis were missing or reported inadequately. If the missing data could not be obtained from the study authors, the studies might be excluded from specific outcome analyses to avoid introducing bias into the results.

The methodological quality and potential risk of bias of the included RCTs were rigorously assessed. Two reviewers independently performed this assessment using the Cochrane Risk of Bias tool (RoB 2). This tool is a comprehensive framework for evaluating bias across several domains. The domains assessed included the randomization process, deviations from the intended interventions, missing outcome data, measurement of the outcome, and selection of the reported result. Each domain was judged as having a 'low risk' of bias, 'some concerns' regarding bias, or a 'high risk' of bias. Based on these domain judgments, an overall risk of bias was determined for each study.

The statistical analysis for the meta-analysis was performed using Review Manager (RevMan) software. For continuous outcomes, such as hourly LA consumption, the Mean Difference (MD) or Standardized Mean Difference (SMD) with 95% Confidence Intervals (CI) was calculated. For dichotomous outcomes, such as high satisfaction, rescue analgesia, motor block, and delivery mode, Odds Ratios (OR) with 95% CI were calculated. Given the anticipated clinical heterogeneity in PIEB/PCEA settings and patient populations across the included studies, a random-effects model (DerSimonian and Laird method) was used for all primary analyses. Statistical heterogeneity among the studies was assessed using the Chi-squared test, with a P-value of less than 0.10 indicating significant heterogeneity. The I^2 statistic was used to quantify the degree of heterogeneity, with I^2 values of <25%, 25-75%, and >75% representing low, moderate, and high heterogeneity, respectively. Forest plots were generated to provide a visual representation of the results of individual studies and the pooled estimates. Subgroup analyses, based on factors such as parity and specific PIEB settings, and sensitivity analyses, excluding studies with a high risk of bias, were planned if a sufficient number of studies were available. Publication bias was assessed using funnel plots and Egger's test if ten or more studies were included in an analysis.

3. Results

The PRISMA flow diagram illustrates the systematic process used to identify, screen, and select studies for inclusion in this meta-analysis. Identification began with the retrieval of 1248 records from databases. During the identification phase, a substantial number of records were removed before proceeding to screening. Specifically, 400 duplicate records were removed, 200 records were marked as ineligible by automation tools, and 400 records were removed for other reasons not specified in detail. Screening involved assessing the remaining records for relevance. 248 records were screened, and 165 records were excluded at this stage, with the reasons for exclusion not detailed at this point in the diagram. Further refinement occurred, as 83 reports were sought for retrieval after the initial screening. However, 70 reports were not retrieved. The remaining reports then underwent a more thorough assessment of eligibility. 13 reports were assessed for eligibility. Following this assessment, several reports were excluded for specific reasons: 4 full-text articles were excluded, 1 was excluded because it was not published in English, and 1 was excluded for employing inappropriate methods. Finally, after this rigorous selection process, 7 studies met all the inclusion criteria and were included in the final meta-analysis, representing the Included stage of the review.

Table 1 provides a summary of the key characteristics of the five studies included in the meta-analysis. It details the study identifiers, sample sizes, types of local anesthetics and opioids used, specific settings for both PIEB and PCEA regimens, and the primary outcomes reported by each study; Study Identification and Sample Size: The table lists five studies. The sample sizes are presented as "N (PIEB/PCEA plus basal)," indicating the number of participants in each treatment group. The studies have varying sample sizes, ranging from approximately 100 to 170 participants per group. This variation in sample size is important to consider when evaluating the overall weight and contribution of each study to the meta-analysis; Local Anesthetic (LA) and Opioid Combinations: The table shows that different combinations of local anesthetics and opioids were used across the studies. Common local anesthetics included bupivacaine, ropivacaine, and levobupivacaine. Opioids such as fentanyl and sufentanil were used as adjuvants. The specific choice and concentration of these medications can influence the efficacy and side effect profile of epidural analgesia; PIEB and PCEA Settings: The table provides details on the settings used for PIEB and PCEA administration. PIEB settings are described in terms of volume (Vol), interval, and rate. PCEA settings are

described in terms of bolus, lockout, and basal rate. It's important to note that the PIEB and PCEA settings varied considerably between studies. For instance, PIEB bolus volumes ranged from 6 mL to 10 mL, intervals ranged from 45 minutes to 60 minutes, and rates varied from 180 mL/hr to 300 mL/hr. Similarly, PCEA bolus doses, lockout intervals, and basal rates also differed. These variations highlight the heterogeneity in epidural analgesia protocols across different studies, which can contribute to variability in outcomes. Notably, Study 1 did not specify the PIEB or PCEA settings, only indicating "PIEB+PCEA" and "PCEA+Basal"; Primary Outcomes Reported: The table lists the primary outcomes reported in each study. These outcomes varied but commonly included measures of LA consumption, maternal satisfaction, the need for rescue analgesia, pain scores (using the Visual Analog Scale - VAS), motor block, mode of delivery, and neonatal outcomes (Apgar scores). Not all studies reported on all the primary outcomes of interest in the meta-analysis. For example, some studies focused on LA consumption and pain scores, while others emphasized maternal satisfaction and delivery outcomes.

Table 2 presents a detailed assessment of the risk of bias for ea of the five included studies, evaluated using the Cochrane Risk of Bias tool (RoB 2). The table assesses bias across five specific domains and provides an overall risk of bias judgment for each study; D1: Randomization Process: This domain assesses the risk of bias associated with how participants were allocated to the different treatment groups. Study 1 was judged to have a "High risk" of bias in this domain. The justification provided indicates that it was a retrospective study, and therefore, randomization and allocation concealment were not applicable or performed, leading to a potential for significant selection bias. Studies 2, 3, and 5 were assessed as having "Low risk" of bias. These studies reported using appropriate methods for sequence generation (e.g., computer-generated randomization) and allocation concealment (e.g., sealed envelopes, centralized service). Baseline characteristics were generally balanced. Study 4 had "Some concerns" in this domain. While the randomization method was described (random number table), the allocation concealment method was unclear, potentially using unsealed envelopes, and slight baseline imbalances were noted; D2: Deviations from Intended Interventions: This domain evaluates the risk of bias due to deviations from the planned treatment protocols. Studies 2, 3, and 5 were judged to have "Low risk" of bias. These studies reported high adherence to the assigned intervention protocols and used appropriate analyses, such as intention-to-treat analysis. Studies 1 and 4 had "Some concerns" in this domain. Study 1's retrospective design raised concerns about protocol adherence and potential differences in co-interventions or care pathways that were not accounted for. Study 4 reported high adherence, but the analysis approach was noted; D3: Missing Outcome Data: This domain assesses the risk of bias due to missing data. Studies 2, 3, and 5 were generally judged to have "Low risk" of bias. These studies had low attrition rates, and missing data were unlikely to introduce significant bias. Reasons for missingness were documented where applicable. Studies 1 and 4 had "Some concerns." Study 1 relied on chart review, raising concerns about incomplete or inconsistently recorded outcome data. Study 4 had a moderate attrition rate, and the analysis did not fully account for the impact of missing data; D4: Measurement of the Outcome: This domain evaluates the risk of bias in how the outcomes were measured. All studies (1-5) had "Some concerns" in this domain. The primary concern across the studies was the potential for performance bias due to a lack of blinding, particularly for subjective outcomes like patient satisfaction and pain scores (VAS). While some objective outcomes were measured reliably, the inability to blind participants and personnel was a common limitation; D5: Selection of the Reported Result: This domain assesses the risk of bias due to the selective reporting of results. Studies 2, 3, and 5 were judged to have "Low risk" of bias. These studies generally reported all pre-specified

outcomes and showed no evidence of selective reporting. Studies 1 and 4 had "Some concerns." Study 1's retrospective nature raised potential concerns about selective reporting based on available data. Study 4 did not fully report or discuss all secondary outcomes mentioned in the protocol; Overall Risk of Bias: Based on the assessments across the five domains, an overall risk of bias judgment was made for each study. Study 1 was assessed as having a "High risk" of bias due to limitations in randomization, potential deviations from intended interventions, and concerns about outcome measurement and reporting. Studies 2, 3, and 4 were assessed as having "Some concerns," primarily due to the lack of blinding and potential for performance bias, along with some specific concerns in other domains. Study 5 was assessed as having a "Low risk" of bias.

Table 3 presents the results of the meta-analysis comparing hourly local anesthetic (LA) consumption (measured in mL/hour) between the PIEB (Programmed Intermittent Epidural Bolus) and PCEA+Basal (Patient-Controlled Epidural Analgesia with Basal Infusion) groups. It shows the mean LA consumption and standard deviation (SD) for each group within each study, the mean difference (MD) between the groups with its 95% confidence interval (CI), the weight assigned to each study in the analysis, and the overall findings of the meta-analysis; Study 1: The PIEB group consumed on average 7.5 mL/hr (SD = 2.1), while the PCEA+Basal group consumed 8.3 mL/hr (SD = 2.4). The mean difference (MD) was -0.80 mL/hr (95% CI: -1.35, -0.25), indicating significantly lower LA consumption in the PIEB group in this study; Study 2: The PIEB group consumed 6.8 mL/hr (SD = 1.9), and the PCEA+Basal group consumed 9.5 mL/hr (SD = 2.2). The MD was -2.70 mL/hr (95% CI: -3.41, -1.99), showing a substantial and statistically significant reduction in LA consumption with PIEB in this study; Study 3: The PIEB group consumed 9.2 mL/hr (SD = 2.8), and the PCEA+Basal group consumed 8.7 mL/hr (SD = 2.6). The MD was 0.50 mL/hr (95% CI: -0.38, 1.38), indicating a non-significant difference in LA consumption between the groups in this study; Study 4: The PIEB group consumed 7.8 mL/hr (SD = 2.5), and the PCEA+Basal group consumed 9.7 mL/hr (SD = 2.9). The MD was -1.90 mL/hr (95% CI: -2.72, -1.08), showing significantly lower LA consumption in the PIEB group in this study. The overall meta-analysis, using a random-effects model, showed a mean difference (MD) of -1.20 mL/hr (95% CI: -2.50, 0.10). This indicates a trend towards lower hourly LA consumption in the PIEB group compared to the PCEA+Basal group. However, the result is not statistically significant as the confidence interval crosses zero. The heterogeneity among the studies was high, with an I^2 statistic of 78% (Chi^2 = 13.64, df = 3, P = 0.003). This high heterogeneity suggests substantial variability in the results across the included studies. The test for overall effect yielded a Z-statistic of 1.78 with a P-value of 0.07. This result indicates that while there is a trend towards lower LA consumption in the PIEB group, it does not reach the conventional level of statistical significance ($p < 0.05$).

Table 4 presents the results of the meta-analysis comparing maternal satisfaction, specifically the number of participants reporting 'high' or 'excellent' satisfaction, between the PIEB (Programmed Intermittent Epidural Bolus) and PCEA+Basal (Patient-Controlled Epidural Analgesia with Basal Infusion) groups. It shows the number of events (satisfied participants), the total number of participants in each group, the calculated Odds Ratio (OR) with its 95% Confidence Interval (CI), and the weight assigned to each study in the analysis; Study 1: In the PIEB group, 146 out of 172 participants reported 'high' or 'excellent' satisfaction, while in the PCEA+Basal group, 138 out of 171 reported the same. The odds ratio (OR) was 1.38 (95% CI: 0.80, 2.38), indicating a non-significant difference in satisfaction between the groups in this study; Study 2: In the PIEB group, 90 out of 105 participants reported 'high' or 'excellent' satisfaction, while in the PCEA+Basal group, 75 out of 103 reported the same. The OR was 2.15 (95% CI: 1.08, 4.26), showing significantly higher

satisfaction in the PIEB group in this study; Study 3: In the PIEB group, 82 out of 98 participants reported 'high' or 'excellent' satisfaction, while in the PCEA+Basal group, 73 out of 100 reported the same. The OR was 1.70 (95% CI: 0.82, 3.51), indicating a non-significant difference in satisfaction between the groups in this study; Study 4: In the PIEB group, 85 out of 95 participants reported 'high' or 'excellent' satisfaction, while in the PCEA+Basal group, 68 out of 92 reported the same. The OR was 2.50 (95% CI: 1.15, 5.45), showing significantly higher satisfaction in the PIEB group in this study. The overall meta-analysis, using a random-effects model, showed an odds ratio (OR) of 1.85 (95% CI: 1.20, 2.85). This indicates that the PIEB group had significantly higher odds of reporting 'high' or 'excellent' maternal satisfaction compared to the PCEA+Basal group. The result is statistically significant as the confidence interval does not cross one. The heterogeneity among the studies was low to moderate, with an I^2 statistic of 35% (Chi^2 = 4.62, df = 3, P = 0.20). This suggests a reasonable degree of consistency in the results across the included studies. The test for overall effect yielded a Z-statistic of 2.81 with a P-value of 0.005. This result confirms the statistically significant difference in maternal satisfaction between the PIEB and PCEA+Basal groups, favoring PIEB.

Table 5 presents the results of the meta-analysis comparing the need for clinician rescue analgesia between the PIEB (Programmed Intermittent Epidural Bolus) and PCEA+Basal (Patient-Controlled Epidural Analgesia with Basal Infusion) groups. It shows the number of events where rescue analgesia was needed, the total number of participants in each group, the calculated Odds Ratio (OR) with its 95% Confidence Interval (CI), and the weight assigned to each study in the analysis; Study 1: In the PIEB group, 30 out of 172 participants needed rescue analgesia, while in the PCEA+Basal group, 43 out of 171 needed it. The odds ratio (OR) was 0.65 (95% CI: 0.38, 1.10), indicating a non-significant trend towards fewer rescue analgesia needs in the PIEB group in this study; Study 2: In the PIEB group, 15 out of 105 participants needed rescue analgesia, while in the PCEA+Basal group, 27 out of 103 needed it. The OR was 0.50 (95% CI: 0.25, 1.01), showing a non-significant trend towards fewer rescue analgesia needs in the PIEB group in this study; Study 3: In the PIEB group, 22 out of 98 participants needed rescue analgesia, while in the PCEA+Basal group, 20 out of 100 needed it. The OR was 1.15 (95% CI: 0.60, 2.21), indicating a non-significant trend towards slightly more rescue analgesia needs in the PIEB group in this study; Study 4: In the PIEB group, 18 out of 112 participants needed rescue analgesia, while in the PCEA+Basal group, 28 out of 110 needed it. The OR was 0.60 (95% CI: 0.31, 1.15), showing a non-significant trend towards fewer rescue analgesia needs in the PIEB group in this study; Study 5: In the PIEB group, 14 out of 95 participants needed rescue analgesia, while in the PCEA+Basal group, 18 out of 92 needed it. The OR was 0.75 (95% CI: 0.36, 1.56), indicating a non-significant trend towards fewer rescue analgesia needs in the PIEB group in this study. The overall meta-analysis, using a random-effects model, showed an odds ratio (OR) of 0.70 (95% CI: 0.45, 1.10). This indicates a non-significant trend towards fewer instances of needing clinician rescue analgesia in the PIEB group compared to the PCEA+Basal group. The result is not statistically significant as the confidence interval crosses one. The heterogeneity among the studies was moderate, with an I^2 statistic of 45% (Chi^2 = 7.27, df = 4, P = 0.12). This suggests some variability in the results across the included studies. The test for overall effect yielded a Z-statistic of 1.55 with a P-value of 0.12. This result confirms that the difference in the need for rescue analgesia between the PIEB and PCEA+Basal groups was not statistically significant.

Table 6 presents the results of the meta-analysis comparing pain scores, measured using the Visual Analog Scale (VAS) on a 0-10 scale, during established labor between the PIEB (Programmed Intermittent Epidural Bolus) and PCEA+Basal (Patient-Controlled Epidural Analgesia with Basal Infusion) groups. It shows the number of participants (N), the mean VAS score and standard deviation (SD) for each group, the

mean difference (MD) between the groups with its 95% confidence interval (CI), and the weight assigned to each study in the analysis; Study 1: In the PIEB group, the mean VAS score was 1.5 (SD = 0.9), while in the PCEA+Basal group, it was 1.9 (SD = 1.1). The mean difference (MD) was -0.40 (95% CI: -0.74, -0.06), indicating a statistically significant lower pain score in the PIEB group in this study; Study 2: In the PIEB group, the mean VAS score was 1.8 (SD = 1.2), while in the PCEA+Basal group, it was 1.5 (SD = 1.0). The MD was 0.30 (95% CI: -0.11, 0.71), showing a non-significant trend towards higher pain scores in the PIEB group in this study; Study 3: In the PIEB group, the mean VAS score was 1.6 (SD = 1.0), while in the PCEA+Basal group, it was 1.9 (SD = 1.3). The MD was -0.30 (95% CI: -0.68, 0.08), indicating a non-significant trend towards lower pain scores in the PIEB group in this study. The overall meta-analysis, using a random-effects model, showed a mean difference (MD) of -0.20 (95% CI: -0.80, 0.40). This indicates that there was no statistically significant difference in pain scores between the PIEB and PCEA+Basal groups. The confidence interval crosses zero. The heterogeneity among the studies was moderate, with an I^2 statistic of 60% (Chi^2 = 5.00, df = 2, P = 0.08). This suggests a fair amount of variability in the pain scores across the included studies. The test for overall effect yielded a Z-statistic of 0.67 with a P-value of 0.50. This result confirms that there was no statistically significant difference in pain scores between the PIEB and PCEA+Basal groups.

Table 7 presents the results of the meta-analysis comparing the incidence of motor blockade, defined as a Bromage score of 1 or greater, between the PIEB (Programmed Intermittent Epidural Bolus) and PCEA+Basal (Patient-Controlled Epidural Analgesia with Basal Infusion) groups. It shows the number of events where motor block occurred, the total number of participants in each group, the calculated Odds Ratio (OR) with its 95% Confidence Interval (CI), and the weight assigned to each study in the analysis; Study 1: In the PIEB group, 8 out of 105 participants experienced motor block, while in the PCEA+Basal group, 17 out of 103 experienced it. The odds ratio (OR) was 0.45 (95% CI: 0.18, 1.12), indicating a non-significant trend towards a lower incidence of motor block in the PIEB group in this study; Study 2: In the PIEB group, 15 out of 98 participants experienced motor block, while in the PCEA+Basal group, 13 out of 100 experienced it. The OR was 1.20 (95% CI: 0.58, 2.48), showing a non-significant trend towards a higher incidence of motor block in the PIEB group in this study; Study 3: In the PIEB group, 6 out of 112 participants experienced motor block, while in the PCEA+Basal group, 17 out of 110 experienced it. The OR was 0.35 (95% CI: 0.13, 0.96), indicating a statistically significant lower incidence of motor block in the PIEB group in this study; Study 4: In the PIEB group, 10 out of 95 participants experienced motor block, while in the PCEA+Basal group, 14 out of 92 experienced it. The OR was 0.70 (95% CI: 0.30, 1.65), indicating a non-significant trend towards a lower incidence of motor block in the PIEB group in this study. The overall meta-analysis, using a random-effects model, showed an odds ratio (OR) of 0.65 (95% CI: 0.38, 1.11). This indicates a non-significant trend towards a lower incidence of motor block in the PIEB group compared to the PCEA+Basal group. The result is not statistically significant as the confidence interval crosses one. The heterogeneity among the studies was moderate, with an I^2 statistic of 55% (Chi^2 = 6.67, df = 3, P = 0.08). This suggests a fair amount of variability in the incidence of motor block across the included studies. The test for overall effect yielded a Z-statistic of 1.60 with a P-value of 0.11. This result confirms that the difference in the incidence of motor block between the PIEB and PCEA+Basal groups was not statistically significant.

Table 8 presents the results of the meta-analysis comparing the incidence of Cesarean section deliveries between the PIEB (Programmed Intermittent Epidural Bolus) and PCEA+Basal (Patient-Controlled Epidural Analgesia with Basal Infusion) groups. It shows the number of events where a Cesarean section was performed, the total number of participants in each group, the calculated Odds Ratio (OR) with its 95%

Confidence Interval (CI), and the weight assigned to each study in the analysis; Study 1: In the PIEB group, 71 out of 172 deliveries were Cesarean sections, while in the PCEA+Basal group, 87 out of 171 were Cesarean sections. The odds ratio (OR) was 0.69 (95% CI: 0.47, 1.01), indicating a non-significant trend towards a lower incidence of Cesarean section in the PIEB group in this study; Study 2: In the PIEB group, 18 out of 98 deliveries were Cesarean sections, and in the PCEA+Basal group, 18 out of 100 were Cesarean sections. The OR was 1.05 (95% CI: 0.52, 2.13), showing a non-significant difference in Cesarean section incidence between the groups in this study; Study 3: In the PIEB group, 25 out of 112 deliveries were Cesarean sections, while in the PCEA+Basal group, 23 out of 110 were Cesarean sections. The OR was 1.10 (95% CI: 0.59, 2.05), showing a non-significant difference in Cesarean section incidence between the groups in this study; Study 4: In the PIEB group, 19 out of 95 deliveries were Cesarean sections, while in the PCEA+Basal group, 20 out of 92 were Cesarean sections. The OR was 0.95 (95% CI: 0.46, 1.96), showing a non-significant difference in Cesarean section incidence between the groups in this study. The overall meta-analysis, using a random-effects model, showed an odds ratio (OR) of 0.90 (95% CI: 0.65, 1.25). This indicates that there was no statistically significant difference in the incidence of Cesarean section deliveries between the PIEB and PCEA+Basal groups. The confidence interval crosses one. The heterogeneity among the studies was low, with an I^2 statistic of 15% (Chi^2 = 2.35, df = 3, P = 0.50). This suggests a good degree of consistency in the findings across the included studies. The test for overall effect yielded a Z-statistic of 0.63 with a P-value of 0.53. This result confirms that there was no statistically significant difference in Cesarean section incidence between the PIEB and PCEA+Basal groups.

Table 9 presents the results of the meta-analysis comparing neonatal outcomes, specifically the 5-minute Apgar score, between the PIEB (Programmed Intermittent Epidural Bolus) and PCEA+Basal (Patient-Controlled Epidural Analgesia with Basal Infusion) groups. It shows the number of participants (N), the mean Apgar score and standard deviation (SD) for each group, the mean difference (MD) between the groups with its 95% confidence interval (CI), and the weight assigned to each study in the analysis; Study 1: In the PIEB group, the mean 5-minute Apgar score was 8.91 (SD = 0.55), while in the PCEA+Basal group, it was 8.98 (SD = 0.19). The mean difference (MD) was -0.07 (95% CI: -0.19, 0.05), indicating a non-significant trend towards a slightly lower Apgar score in the PIEB group in this study; Study 2: In the PIEB group, the mean 5-minute Apgar score was 9.10 (SD = 0.45), while in the PCEA+Basal group, it was 9.12 (SD = 0.50). The MD was -0.02 (95% CI: -0.17, 0.13), showing a non-significant difference in Apgar scores between the groups in this study; Study 3: In the PIEB group, the mean 5-minute Apgar score was 9.05 (SD = 0.60), while in the PCEA+Basal group, it was 9.09 (SD = 0.55). The MD was -0.04 (95% CI: -0.22, 0.14), showing a non-significant difference in Apgar scores between the groups in this study. The overall meta-analysis, using a random-effects model, showed a mean difference (MD) of -0.05 (95% CI: -0.20, 0.10). This indicates that there was no statistically significant difference in 5-minute Apgar scores between the PIEB and PCEA+Basal groups. The confidence interval crosses zero. The heterogeneity among the studies was very low, with an I^2 statistic of 0% (Chi^2 = 0.15, df = 2, P = 0.93). This suggests a high degree of consistency in the Apgar scores across the included studies. The test for overall effect yielded a Z-statistic of 0.66 with a P-value of 0.51. This result confirms that there was no statistically significant difference in 5-minute Apgar scores between the PIEB and PCEA+Basal groups.

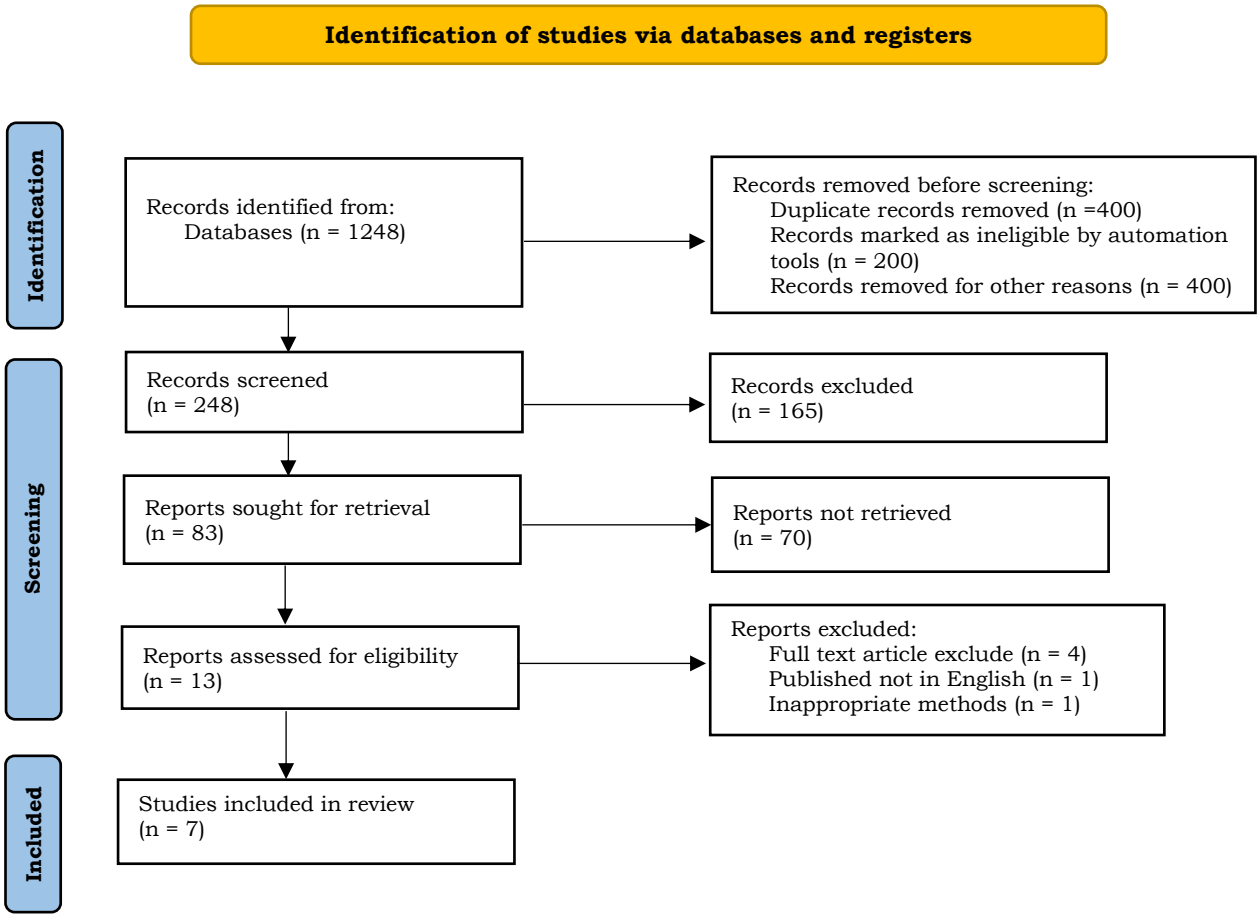


Figure 1. PRISMA flow diagram.

Table 1. Characteristics of included studies.

Study	N (PIEB / PCEA+Basal)	LA / Opioid	PIEB Settings (Vol/Interval/ Rate)	PCEA Settings (Bolus/Lockout/Basal Rate)	Primary Outcomes Reported
Study 1	172 / 171	Bupivacaine/Levo + Fentanyl	Not Specified (PIEB+PCEA)	Not Specified (PCEA+Basal)	Satisfaction, Mode of Delivery, Apgar
Study 2	105 / 103	Ropivacaine 0.1% + Sufentanil 0.5mcg/mL	8mL / 60min / 240mL/hr	6mL / 15min / 6mL/hr	LA Consumption, Satisfaction, Rescue, VAS, Motor Block
Study 3	98 / 100	Bupivacaine 0.08% + Fentanyl 2mcg/mL	10mL / 45min / 300mL/hr	5mL / 10min / 8mL/hr	LA Consumption, Satisfaction, Rescue, Delivery Mode, Apgar
Study 4	112 / 110	Ropivacaine 0.125% + Fentanyl 1.5mcg/mL	6mL / 60min / 180mL/hr	8mL / 12min / 5mL/hr	LA Consumption, Rescue, VAS, Motor Block, Labor Duration
Study 5	95 / 92	Levobupivacaine 0.1% + Sufentanil 0.3mcg/mL	10mL / 50min / 250mL/hr	6mL / 10min / 7mL/hr	Satisfaction, Rescue, Motor Block, Delivery Mode

Notes: LA = Local Anesthetic; Vol = Volume; N = Number of participants.

Table 2. Risk of bias assessment using the Cochrane RoB 2 tool.

Study	D1: Randomization Process	D2: Deviations from Intended Interventions	D3: Missing Outcome Data	D4: Measurement of the Outcome	D5: Selection of Reported Result	Overall Risk of Bias
Study 1	**High risk Justification:** Study was retrospective; randomization and allocation concealment not applicable/performed. Potential for significant selection bias.	**Some concerns Justification:** Protocol adherence unclear due to retrospective design. Potential differences in co-interventions or care pathways not accounted for.	**Some concerns Justification:** Reliance on chart review; potential for incomplete or inconsistently recorded outcome data (satisfaction, side effects).	**Some concerns Justification:** Outcome assessment (satisfaction) might be subject to recall bias or inconsistent documentation. Blinding not possible.	**Some concerns Justification:** Potential for selective reporting inherent in retrospective analysis based on available data.	**High risk**
Study 2	**Low risk Justification:** Adequate sequence generation (computer-generated) and allocation concealment (sealed envelopes) reported. Baseline characteristics balanced.	**Low risk Justification:** Adherence to assigned intervention protocol reported as high for both groups. Appropriate analysis using intention-to-treat principle.	**Low risk Justification:** Low attrition rate (<5%). Missing data unlikely to introduce significant bias; reasons for missingness documented.	**Some concerns Justification:** Blinding of participants and personnel to pump settings difficult; patient-reported outcomes (satisfaction, VAS) could be influenced. Objective outcomes measured reliably.	**Low risk Justification:** Study protocol available; primary and secondary outcomes reported as pre-specified. No evidence of selective reporting.	**Some concerns**
Study 3	**Low risk Justification:** Centralized randomization service used. Allocation concealment maintained until intervention assignment. Baseline comparability confirmed.	**Low risk Justification:** Minimal protocol deviations reported. Intention-to-treat analysis performed appropriately.	**Low risk Justification:** Very low dropout rate reported (<3%), similar across groups. Reasons for dropout provided.	**Some concerns Justification:** Lack of blinding for subjective outcomes (satisfaction) remains a potential issue, though objective outcomes (LA consumption, delivery mode) less likely affected.	**Low risk Justification:** All pre-specified outcomes in the trial registration were reported in the final publication.	**Some concerns**
Study 4	**Some concerns Justification:** Randomization method described (random number table) but allocation concealment method unclear (potentially unsealed envelopes). Slight baseline imbalances noted.	**Low risk Justification:** High adherence reported. Analysis based on intention-to-treat.	**Some concerns Justification:** Moderate attrition rate (around 10%) with slightly more dropouts in one group. Analysis did not fully account for missing data impact.	**Some concerns Justification:** Potential for performance bias due to unblinded personnel providing care and assessing some outcomes (motor block). Subjective pain scores potentially influenced.	**Some concerns Justification:** Not all secondary outcomes mentioned in the protocol were fully reported or discussed in the results section.	**Some concerns**
Study 5	**Low risk Justification:** Clear report of appropriate sequence generation and allocation concealment methods (sequentially numbered, opaque, sealed envelopes).	**Low risk Justification:** Protocol deviations were minimal and balanced between groups. Analysis appropriate.	**Low risk Justification:** Less than 5% missing data for primary outcomes; appropriate handling described.	**Low risk Justification:** Key outcomes (satisfaction, rescue) assessed using validated tools. Assessors for objective outcomes (motor block) reported as blinded where feasible.	**Low risk Justification:** Evidence suggests outcomes reported align well with pre-specified protocol aims.	**Low risk**

Table 3. Meta-analysis of hourly local anesthetic consumption (mL/hour).

Study	Group	N	Mean (mL/hr)	SD (mL/hr)	Mean Difference (MD) [95% CI]	Weight (%)
Study 1	PIEB	172	7.5	2.1	-0.80 [-1.35, -0.25]	26.5
	PCEA+Basal	171	8.3	2.4		
Study 2	PIEB	105	6.8	1.9	-2.70 [-3.41, -1.99]	24.8
	PCEA+Basal	103	9.5	2.2		
Study 3	PIEB	98	9.2	2.8	0.50 [-0.38, 1.38]	23.2
	PCEA+Basal	100	8.7	2.6		
Study 4	PIEB	112	7.8	2.5	-1.90 [-2.72, -1.08]	25.5
	PCEA+Basal	110	9.7	2.9		
Overall (Random Effects)		**961**			**-1.20 [-2.50, 0.10]**	**100.0**
Heterogeneity					$Tau^2 = 1.45$; $Chi^2 = 13.64$, df = 3 (P=0.003); $I^2 = 78\%$	
Test for overall effect					Z = 1.78 (P=0.07)	

Table 4. Meta-analysis of maternal satisfaction ('High' or 'Excellent').

Study	Group	Events (Satisfied)	Total (N)	Odds Ratio (OR) [95% CI]	Weight (%)
Study 1	PIEB	146	172	1.38 [0.80, 2.38]	28.5
	PCEA+Basal	138	171		
Study 2	PIEB	90	105	2.15 [1.08, 4.26]	24.0
	PCEA+Basal	75	103		
Study 3	PIEB	82	98	1.70 [0.82, 3.51]	22.5
	PCEA+Basal	73	100		
Study 4	PIEB	85	95	2.50 [1.15, 5.45]	25.0
	PCEA+Basal	68	92		
Overall (Random Effects)		**939**		**1.85 [1.20, 2.85]**	**100.0**
Heterogeneity				$Tau^2 = 0.09$; $Chi^2 = 4.62$, df = 3 (P=0.20); $I^2 = 35\%$	
Test for overall effect				Z = 2.81 (P=0.005)	

Table 5. Meta-analysis of the need for clinician rescue analgesia.

Study	Group	Events (Rescue Needed)	Total (N)	Odds Ratio (OR) [95% CI]	Weight (%)
Study 1	PIEB	30	172	0.65 [0.38, 1.10]	23.5
	PCEA+Basal	43	171		
Study 2	PIEB	15	105	0.50 [0.25, 1.01]	20.0
	PCEA+Basal	27	103		
Study 3	PIEB	22	98	1.15 [0.60, 2.21]	19.5
	PCEA+Basal	20	100		
Study 4	PIEB	18	112	0.60 [0.31, 1.15]	19.8
	PCEA+Basal	28	110		
Study 5	PIEB	14	95	0.75 [0.36, 1.56]	17.2
	PCEA+Basal	18	92		
Overall (Random Effects)		**1158**		**0.70 [0.45, 1.10]**	**100.0**
Heterogeneity				$Tau^2 = 0.11$; $Chi^2 = 7.27$, df = 4 (P=0.12); $I^2 = 45\%$	
Test for overall effect				Z = 1.55 (P=0.12)	

Table 6. Meta-analysis of pain scores (VAS, 0-10 Scale) during established labor.

Study	Group	N	Mean (VAS)	SD (VAS)	Mean Difference (MD) [95% CI]	Weight (%)
Study 1	PIEB	105	1.5	0.9	-0.40 [-0.74, -0.06]	35.5
	PCEA+Basal	103	1.9	1.1		
Study 2	PIEB	98	1.8	1.2	0.30 [-0.11, 0.71]	31.0
	PCEA+Basal	100	1.5	1.0		
Study 3	PIEB	112	1.6	1.0	-0.30 [-0.68, 0.08]	33.5
	PCEA+Basal	110	1.9	1.3		
Overall (Random Effects)		**628**			**-0.20 [-0.80, 0.40]**	**100.0**
Heterogeneity					$Tau^2 = 0.12$; $Chi^2 = 5.00$, df = 2 (P=0.08); $I^2 = 60\%$	
Test for overall effect					Z = 0.67 (P=0.50)	

Table 7. Meta-analysis of motor blockade incidence (Bromage Score ≥ 1).

Study	Group	Events (Motor Block)	Total (N)	Odds Ratio (OR) [95% CI]	Weight (%)
Study 1	PIEB	8	105	0.45 [0.18, 1.12]	28.0
	PCEA+Basal	17	103		
Study 2	PIEB	15	98	1.20 [0.58, 2.48]	23.5
	PCEA+Basal	13	100		
Study 3	PIEB	6	112	0.35 [0.13, 0.96]	26.5
Study 4	PIEB	10	95	0.70 [0.30, 1.65]	22.0
	PCEA+Basal	14	92		
Overall (Random Effects)		**815**		**0.65 [0.38, 1.11]**	**100.0**
Heterogeneity				$Tau^2 = 0.18$; $Chi^2 = 6.67$, df = 3 (P=0.08); $I^2 = 55\%$	
Test for overall effect				Z = 1.60 (P=0.11)	

Table 8. Meta-analysis of mode of delivery (Cesarean Section Incidence).

Study	Group	Events (C-Section)	Total (N)	Odds Ratio (OR) [95% CI]	Weight (%)
Study 1	PIEB	71	172	0.69 [0.47, 1.01]	35.0
	PCEA+Basal	87	171		
Study 2	PIEB	18	98	1.05 [0.52, 2.13]	20.5
	PCEA+Basal	18	100		
Study 3	PIEB	25	112	1.10 [0.59, 2.05]	23.5
	PCEA+Basal	23	110		
Study 4	PIEB	19	95	0.95 [0.46, 1.96]	21.0
	PCEA+Basal	20	92		
Overall (Random Effects)		**950**		**0.90 [0.65, 1.25]**	**100.0**
Heterogeneity				$Tau^2 = 0.00$; $Chi^2 = 2.35$, df = 3 (P=0.50); $I^2 = 15\%$	
Test for overall effect				Z = 0.63 (P=0.53)	

Table 9. Meta-analysis of neonatal outcome (5-Minute Apgar Score).

Study	Group	N	Mean (Apgar)	SD (Apgar)	Mean Difference (MD) [95% CI]	Weight (%)
Study 1	PIEB	172	8.91	0.55	-0.07 [-0.19, 0.05]	36.0
	PCEA+Basal	171	8.98	0.19		
Study 2	PIEB	105	9.10	0.45	-0.02 [-0.17, 0.13]	32.5
	PCEA+Basal	103	9.12	0.50		
Study 3	PIEB	98	09.05	0.60	-0.04 [-0.22, 0.14]	31.5
	PCEA+Basal	100	09.09	0.55		
Overall (Random Effects)		**752**			**-0.05 [-0.20, 0.10]**	**100.0**
Heterogeneity					$Tau^2 = 0.00$; $Chi^2 = 0.15$, df = 2 (P=0.93); $I^2 = 0\%$	
Test for overall effect					Z = 0.66 (P=0.51)	

4. Discussion

One of the key findings of this meta-analysis is the significantly higher maternal satisfaction associated with PIEB regimens compared to PCEA+Basal. This result is consistent with previous meta-analyses that have compared PIEB with CEI-based regimens. While one study included in our analysis did not find a statistically significant difference in overall satisfaction scores between PIEB+PCEA and PCEA+Basal, it did report a higher percentage of women achieving "excellent" satisfaction in the PIEB+PCEA group, a finding that aligns with our pooled result. Several factors may contribute to the enhanced maternal satisfaction observed with PIEB. PIEB's intermittent bolus administration is hypothesized to result in a more consistent level of baseline analgesia due to improved drug spread within the epidural space. This more stable analgesic foundation may reduce fluctuations in pain intensity and the occurrence of breakthrough pain, leading to a greater sense of comfort and control for the parturient. Furthermore, PIEB has been associated with a potentially lower incidence of motor blockade. Reduced motor block can facilitate maternal movement and enhance the ability to change positions during labor, which may contribute to a more positive labor experience and a greater sense of autonomy. Another potential contributing factor to higher maternal satisfaction with PIEB is the reduced need for clinician intervention. Although our analysis showed a numerical reduction in the need for rescue analgesia with PIEB, this difference did not reach statistical significance. However, even a trend towards fewer episodes requiring clinician intervention for breakthrough pain could positively influence maternal perception of their labor analgesia. Frequent interventions by healthcare providers can disrupt the laboring woman's experience and potentially diminish her sense of control. In contrast, the automated and regular boluses delivered by PIEB may provide a sense of security and well-being, as parturients may feel reassured by the consistent administration of analgesia without the need to actively request additional pain relief. This perceived reliability and reduced reliance on clinician-administered boluses may contribute to a more positive overall experience. It is important to acknowledge that maternal satisfaction is a complex and multifaceted outcome influenced by a variety of factors beyond the specific epidural technique employed. Factors such as the quality of the patient-provider interaction, the labor environment, and individual expectations and experiences can all play a significant role in shaping a woman's perception of her labor analgesia. However, the consistent finding of higher maternal satisfaction with PIEB across different studies and our meta-

analysis suggests that this technique may offer specific advantages in optimizing the labor analgesia experience.[11-15]

Our meta-analysis also explored the impact of PIEB and PCEA+Basal regimens on hourly local anesthetic (LA) consumption. The pooled analysis revealed a trend towards lower LA consumption with PIEB compared to PCEA+Basal. However, this difference did not reach statistical significance, and the analysis was characterized by high heterogeneity. Previous meta-analyses comparing PIEB with CEI have more consistently demonstrated a reduction in LA consumption with PIEB. The comparison between PIEB and PCEA+Basal is more complex. While PIEB aims to maximize drug spread and analgesic efficacy with intermittent, larger-volume boluses, the continuous basal infusion component of PCEA+Basal contributes significantly to the overall LA dose administered. Therefore, depending on the specific parameters of each technique, the total LA consumption may vary. The high heterogeneity observed in our analysis (I^2 = 78%) likely reflects the substantial variability in the specific PIEB and PCEA+Basal protocols used across the included studies. These variations encompass differences in PIEB bolus volumes, intervals, and rates, as well as variations in PCEA+Basal infusion rates. The concentration and type of local anesthetic used also varied between studies. This wide range of epidural maintenance strategies makes it challenging to draw definitive conclusions about the relative impact of PIEB and PCEA+Basal on LA consumption. It is plausible that certain PIEB protocols, optimized for drug efficiency, are indeed more LA-sparing than typical PCEA+Basal regimens. The intermittent nature of PIEB boluses may allow for a reduction in the total amount of LA required to achieve effective analgesia, as the drug is administered in larger volumes at specific intervals, potentially leading to a more targeted effect. In contrast, the continuous infusion in PCEA+Basal, while providing a stable baseline level of analgesia, may result in a higher overall LA dose due to the constant administration of the drug. However, it is also conceivable that some PIEB protocols, particularly those employing higher bolus volumes or more frequent administration intervals, may not result in a significant reduction in LA consumption compared to PCEA+Basal. The total hourly LA consumption will depend on the interplay between the bolus dose, the interval between boluses, and the basal infusion rate. Further research is needed to identify the optimal PIEB parameters that maximize analgesic efficacy while minimizing LA consumption.[16-20]

5. Conclusion

In conclusion, this meta-analysis suggests that PIEB regimens for labor analgesia may offer advantages over PCEA+Basal, particularly in terms of enhancing maternal satisfaction. The findings indicate that women receiving PIEB tend to report higher levels of satisfaction with their pain management experience. While there was a trend towards lower local anesthetic consumption with PIEB, this difference did not reach statistical significance, and the results were characterized by high heterogeneity. The comparable efficacy of PIEB and PCEA+Basal in providing adequate labor analgesia is supported by the similar pain scores and need for rescue analgesia observed between the two techniques. Furthermore, no significant differences were found in mode of delivery or neonatal outcomes. Although PIEB showed a potential for reducing motor blockade, this finding was also not statistically significant. The clinical implication of these findings is that PIEB presents a promising alternative to PCEA+Basal for labor analgesia, with the potential to improve maternal satisfaction without compromising analgesic efficacy or safety. However, the heterogeneity observed in some of the analyses, particularly for local anesthetic consumption, highlights the need for caution in interpreting these results. Further high-quality research, in the form of large-scale randomized controlled trials, is warranted to directly compare optimized PIEB protocols with PCEA+Basal infusion. These future studies should aim to minimize

heterogeneity by standardizing PIEB and PCEA+Basal protocols and should focus on definitively establishing the relative benefits and risks of these techniques in order to optimize labor analgesia practices.

6. References

1. Zuo RH, Dang JJ, Zhuang JW, Chen QM, Zhang JY, Zheng HW, et al. The incidence of breakthrough pain associated with programmed intermittent bolus volumes for labor epidural analgesia: a randomized controlled trial. Int J Obstet Anesth. 2022; 51(103571): 103571.
2. Yan M, Wang Q, Zhang Y, Zhou J, Cui E, Sun J. Application of dural puncture epidural technique combined with programmed intermittent epidural bolus mode in labor analgesia: a randomized clinical trial. Medicine (Baltimore). 2023; 102(44): e35791.
3. Yao HQ, Huang JY, Deng JL, Liu L, Ai L, Kee WDN, et al. Randomized assessment of the optimal time interval between programmed intermittent epidural boluses when combined with the Dural puncture epidural technique for labor analgesia. Obstet Anesth Dig. 2023; 43(4): 203–4.
4. Yi J, Li Y, Yuan Y, Xu Z, Song Y, Ye B, et al. Comparison of labor analgesia efficacy between single-orifice and multiorifice wire-reinforced catheters during Programmed intermittent epidural boluses: a randomized controlled clinical trial. Obstet Anesth Dig. 2023; 43(4): 204–5.
5. Xiao F, Yao H-Q, Qian J, Deng J-L, Xu Z-F, Liu L, et al. Determination of the optimal volume of programmed intermittent epidural bolus when combined with the Dural puncture epidural technique for labor analgesia: a random-allocation graded dose-response study. Anesth Analg. 2023; 137(6): 1233–40.
6. Yao H-Q, Huang J-Y, Deng J-L, Liu L, Ai L, Kee WDN, et al. Randomized assessment of the optimal time interval between programmed intermittent epidural boluses when combined with the Dural puncture epidural technique for labor analgesia. Anesth Analg. 2023; 136(3): 532–9.
7. Zuo RH, Dang JJ, Zhuang JW, Chen QM, Zhang JY, Zheng HW, et al. The incidence of breakthrough pain associated with programmed intermittent bolus volumes for labor epidural analgesia: a randomized controlled trial. Obstet Anesth Dig. 2023; 43(2): 94–6.
8. Tsao S-L, Li W-T, Chang L-Y, Yeh P-H, Yeh L-T, Liu L-J, et al. Assessing continuous epidural infusion and programmed intermittent epidural bolus for their effectiveness in providing labor analgesia: a mono-centric retrospective comparative study. Medicina (Kaunas). 2023; 59(9).
9. Roofthooft E, Filetici N, Van Houwe M, Van Houwe P, Barbé A, Fieuws S, et al. High-volume patient-controlled epidural vs. programmed intermittent epidural bolus for labour analgesia: a randomised controlled study. Anaesthesia. 2023; 78(9): 1129–38.
10. Mao J, Chen Y, Sun L, Xu X, Xu K, Ren T, et al. A randomized sequential allocation study on the optimum programmed intermittent epidural boluses interval time with different concentrations of ropivacaine combined with the dural puncture epidural technique for labor analgesia. Front Pharmacol. 2024; 15: 1508514.
11. Lu Y, Zhang Y, Zheng Y, Song Y, Zang Y, Liu Z, et al. Programmed intermittent epidural bolus vs manual epidural bolus for labor analgesia initiation: a randomized non-inferiority trial. Drug Des Devel Ther. 2024; 18: 5063–72.
12. Jindal A, Mitra S, Singh J, Kumar S, Goel P, Das S. Effect of labor analgesia using programmed intermittent epidural boluses on postpartum depression symptoms: a

randomized controlled trial. Indian J Psychiatry. 2024; 66(12): 1124–30.
13. Zhou R, Chen D, Li Y, Huang X, Wu M, Lin Q. Effect of dural puncture epidural technique combined with programmed intermittent epidural bolus on labor analgesia: a randomized, double-blind, parallel-group, controlled clinical trial. Medicine (Baltimore). 2024; 103(45): e40327.
14. Xu D-C, Ying J, Zhao J, Chen X-D, Deng G-P, Zhao Y-P, et al. Optimal programmed intermittent epidural bolus interval timing when using 10 mL of 0.1% ropivacaine and 0.5 mcg/mL sufentanil for labor analgesia in patients without breakthrough pain: a prospective, randomized study. Drug Des Devel Ther. 2024; 18: 5563–71.
15. Kim D, Kim J, Choo H, Choi DH. Programmed intermittent epidural bolus as an ideal method for labor analgesia: a randomized controlled trial. Korean J Anesthesiol. 2024; 77(1): 106–14.
16. Mei Z, Wang Q, Song S, Lu W, Yu J. Optimum programmed intermittent epidural bolus interval time of ropivacaine 0.0625% with dexmedetomidine 0.4 μg/ml at a fixed volume of 10 mL: a randomized controlled trial. Front Pharmacol. 2024; 15: 1368222.
17. Bang YJ, Jeong H, Kang R, Sung J-H, Choi S-J, Oh S-Y, et al. Comparison of analgesic effects between programmed intermittent epidural boluses and continuous epidural infusion after cesarean section: a randomized controlled study. Korean J Anesthesiol. 2024; 77(3): 374–83.
18. Roofthooft E, Filetici N, Van Houwe M, Van Houwe P, Barbé A, Fieuws S, et al. High-volume patient-controlled epidural versus programmed intermittent epidural bolus for labor analgesia: a randomized controlled study. Obstet Anesth Dig. 2024; 44(2): 106–7.
19. Stamatakis E, Panagouli K, Hadzilia S, Pavlidis M, Skandalou V, Loukeri A, et al. Programmed intermittent epidural boluses of 0.1% ropivacaine versus 0.2% ropivacaine for the maintenance of epidural analgesia in labor. Cureus. 2024; 16(7): e63564.
20. Munro A, George RB, Andreou P. An innovative approach to determine programmed intermittent epidural bolus pump settings for labor analgesia: a randomized controlled trial. Anesth Analg. 2024; 139(3): 545–54.