# Comparative Effectiveness of Spinal Versus Epidural Anesthesia in Caesarean Section Delivery: A Systematic Review of Maternal, Fetal, and Neonatal Outcomes

Ghada Eid Alanazi[1], Rahaf Maqil T Alanazi[2], Asma Zaid M Alayyashi[2], Fai Fihat S Almatrafi[2], Rasha Mohammed M Alanazi[3], Abdullah Ali A Aldaossriy[4], Shahad Mohammed F Alanazi[5], Abdullah Tulayhan Aldalaan[6], Yahya Mahmoud A Alsahabi[7,]

[1] Medical Student, Northern Border University, Arar, Saudi Arabia
[2] Medical Intern, Northern Border University, Arar, Saudi Arabia
[3] General Practitioner, Northern Borders Health Cluster, Prince Abdullah bin Abdulaziz bin Musaed Center for Cardiology and Cardiac Surgery in Arar, Saudi
[4] General Practitioner, Emergency department, North medical tower hospital, Arar, Saudi Arabia
[5] General Practitioner, Home and Virtual Care, Northern Borders Health Cluster, Arar, Saudi Arabia
[6] Acting anesthesia consultant, Anesthesia Department, King Fahad Medical City, Saudi Arabia
[7] Consultant-Anesthesia/Obstetrics, Anesthesia/Obstetrics Anesthesia, King Fahad Medical City, Saudi Arabia

**Abstract**

**Background:** Spinal and epidural anesthesia are the dominant neuraxial techniques for caesarean delivery, but their comparative effects on maternal and neonatal outcomes remain uncertain. This systematic review aimed to compare the safety and effectiveness of spinal versus epidural anesthesia for caesarean section, focusing on hemodynamic, fetal, and neonatal endpoints.

**Methods:** Electronic databases (PubMed/MEDLINE, Scopus, Web of Science Core Collection) and trial registries were searched from 1 January 2000 to 30 June 2025, with an update to 30 November 2025. Randomised controlled trials and high-quality comparative cohort studies of pregnant individuals ≥18 years undergoing elective or emergency caesarean section were eligible if they directly compared spinal with epidural anesthesia and reported prespecified maternal or neonatal outcomes. Risk of bias was assessed using RoB 2 for RCTs and ROBINS-I for non-randomised studies, and evidence certainty appraised with GRADE. Ten studies met inclusion criteria (two Cochrane reviews and eight primary comparative studies; total N = 3,877).

**Results:** Across trials, spinal anesthesia consistently achieved faster onset and shorter time to surgical readiness than epidural techniques. However, spinal was associated with substantially higher rates of maternal hypotension and vasopressor use, and more intraoperative bradycardia and nausea, while epidural provided greater hemodynamic stability. Neonatal 1- and 5-minute Apgar scores were generally higher, or at least not inferior, with spinal compared with epidural, and some studies reported marginally higher umbilical artery pH with spinal, whereas a network meta-analysis suggested epidural may optimise umbilical venous pH. Both techniques yielded low rates of serious neonatal morbidity, with no consistent differences in NICU admission or acidosis. Postoperative analgesia duration tended to be longer with spinal, but epidural permitted extended analgesia when catheters were used.

**Conclusion:** Both spinal and epidural anesthesia provide effective neuraxial options for caesarean delivery. Spinal may be preferred when rapid onset and superior early neonatal scores are prioritised, whereas epidural may be favoured in women at high risk of hemodynamic instability or when prolonged titratable block is desired. Further adequately powered trials are needed to clarify long-term maternal and neonatal outcomes and cost-effectiveness.

**Keywords:** spinal anesthesia; epidural anesthesia; caesarean section; maternal hypotension; neonatal Apgar score; umbilical cord pH; neuraxial anesthesia; systematic review.

## **1.** BACKGROUND

### 1.1 Epidemiology of Caesarean Delivery and Anesthetic Considerations

Caesarean delivery has become a major surgical procedure across the globe, with increasing prevalence in both high-income and low-income healthcare settings. The proportion of births delivered via caesarean section has risen substantially over the past three decades, driven by increased maternal age, obesity, multiple gestations, and rising rates of labour dystocia and fetal distress indications.[1] [2] Contemporary caesarean delivery rates vary widely by country and institution, ranging from 10% in Nordic countries to over 40% in some Latin American and Asian regions.[1] As rates of caesarean births have increased, the selection of appropriate anesthetic technique has gained considerable clinical and public health importance, with potential implications for maternal morbidity, neonatal well-being, and healthcare resource allocation. [2]

### 1.2 Neurophysiology and Technical Characteristics of Spinal and Epidural Anesthesia

Spinal anesthesia for caesarean delivery involves injection of local anesthetic agent directly into the cerebrospinal fluid (CSF) within the subarachnoid space, typically administered via a single intrathecal injection at the L3–L4 or L4–L5 vertebral interspace using a fine-gauge needle (typically 24–27 gauge).[2] [3] [4] Common agents include hyperbaric bupivacaine (0.5–15 mg), ropivacaine (15–20 mg), or prilocaine, frequently supplemented with lipophilic opioids such as fentanyl (10–25 μg) or morphine (100–150 μg) to enhance analgesia and extend block duration.[3] [4] The onset of spinal anesthesia is typically rapid, with effective surgical anesthesia achieved within 5–10 minutes of injection.[4]

Epidural anesthesia for caesarean section requires insertion of a larger-bore needle (typically 16–18 gauge) into the epidural space, followed by threading of a catheter through which local anesthetic solution is administered in bolus doses or via continuous infusion.[2] [3] [4] Common agents include bupivacaine (0.5–1.0%), ropivacaine (0.5–1.0%), lidocaine (1.5%), often combined with opioids (fentanyl 50–100 μg, morphine 2–
4 mg).[3] [4] Epidural anesthesia permits more gradual onset of neural blockade, with effective surgical anesthesia typically achieved within 15–20 minutes of initial injection; this delayed onset may permit superior cardiovascular stability compared to spinal techniques.[2] [3]

### 1.3 Pathophysiology of Neuraxial Anesthesia-Induced Hypotension and Fetal Consequences

The sympathetic nervous system blockade induced by both spinal and epidural anesthesia results in peripheral vasodilation and loss of sympathetic vascular tone, leading to decreased systemic vascular resistance (SVR) and venous return, ultimately reducing maternal cardiac output and arterial blood pressure.[5] [6] In spinal anesthesia, this sympatholytic response occurs acutely due to rapid subarachnoid spread of local anesthetic, whereas in epidural anesthesia, the more gradual onset of blockade typically

permits compensatory autonomic responses and generally results in lesser hypotensive effects.[5] [6] The pregnant patient represents a distinct physiological state with baseline increases in circulating catecholamines, enhanced sympathetic tone, and reduced sympathetic reserve capacity compared to non-pregnant individuals; these adaptations paradoxically render pregnant women more susceptible to severe hypotension when sympathetic blockade is suddenly imposed.[5] [6]

### 1.4 Comparative Outcome Literature and Evidence Gaps

Prior systematic reviews and meta-analyses have compared spinal and epidural anesthesia across multiple outcomes, with conflicting or inconclusive findings regarding secondary outcomes such as postoperative nausea and vomiting (PONV), postdural puncture headache (PDPH), and postoperative analgesic requirements.[2] [3] [4] The most recent Cochrane systematic review (2004) that directly compared spinal versus epidural anesthesia for caesarean section included 10 randomised controlled trials and identified key differences in onset time and hypotension incidence, but noted substantial under-reporting of intraoperative complications, postoperative outcomes, and breastfeeding success.[2] Subsequent network meta-analyses have compared multiple anesthetic modalities (including general, spinal, epidural, and combined spinalepidural techniques) across neonatal outcomes, with evidence suggesting spinal anesthesia may confer advantages in neonatal Apgar scores relative to general anesthesia, yet limited direct comparative data between spinal and epidural techniques for neonatal outcomes beyond Apgar scores.[3] [4] Contemporary evidence gaps include: (i) comparative effectiveness of spinal versus epidural anesthesia specifically for umbilical artery and venous pH and acid-base status; (ii) incidence and clinical significance of side-effects such as PDPH, severe pruritus, and postoperative backache; (iii) impact on breastfeeding initiation and success; (iv) long-term maternal outcomes including chronic postoperative pain and quality of life; and (v) cost-effectiveness analyses stratified by technique and risk factors.[2] [3] [4]

### 1.5 Clinical Equipoise and Rationale for Systematic Review

Despite the widespread use of both spinal and epidural anesthesia for caesarean section, clinical practice varies markedly across institutions and healthcare systems, reflecting genuine clinical equipoise regarding the optimal technique.[2] [3] [4] No single anesthetic modality has been definitively established as superior for all pregnant patients and clinical scenarios; rather, the choice between spinal and epidural techniques depends on patient factors (anticipated blood loss, hemodynamic stability, platelet count), provider experience, institutional resources, and individual patient preferences regarding onset speed versus gradual onset and postoperative analgesia options.[2] [3] [4] This systematic review was undertaken to synthesise current evidence on the comparative effectiveness of spinal versus epidural anesthesia for caesarean delivery, with the dual objectives of quantifying differences in key maternal and neonatal outcomes and identifying areas requiring further primary research.

## 2. Objectives and Study Question

### 2.1 Primary Research Question

What are the comparative effects of spinal anesthesia versus epidural anesthesia on maternal, fetal, and neonatal outcomes in pregnant individuals undergoing caesarean section delivery across any indication or gestational age?

### 2.2 Population, Intervention, Comparator, and Outcomes (PICO) Framework

**Population:** Pregnant individuals aged 18 years or older undergoing scheduled or emergency caesarean section delivery at any gestational age or clinical indication. Inclusion encompassed both singleton and multiple pregnancies; singleton pregnancies were the primary analysis with subgroup stratification for multiple gestations where data permitted.

**Intervention:** Spinal anesthesia administered as single-shot intrathecal injection of local anesthetic agent (bupivacaine, ropivacaine, prilocaine, or other agents), with or without supplemental intrathecal opioids (fentanyl, morphine, sufentanil).
**Comparator:** Epidural anesthesia administered via catheter with bolus dosing or continuous infusion of local anesthetic with or without opioids.
**Outcomes:**
**Primary Outcomes:**
1. Maternal hypotension (incidence, severity defined as systolic blood pressure <90 mmHg or mean arterial pressure <60 mmHg, need for vasopressor support with quantification of vasopressor type and dose)
2. Maternal bradycardia (incidence, severity, management)
3. Neonatal Apgar score at 1 minute and 5 minutes (reported as mean ± standard deviation or median [interquartile range])
4. Umbilical artery and venous pH and base excess (quantitative measures of fetal acid-base status)
5. Neonatal need for resuscitation
**Secondary Outcomes:**
1. Time to onset of surgical anesthesia (defined as time from injection to attainment of surgical anesthesia)
2. Maternal postoperative nausea and vomiting (PONV) and requirement for antiemetic intervention
3. Postdural puncture headache (PDPH) incidence and clinical sequelae
4. Pruritus incidence (if opioid-containing local anesthetic used)
5. Maternal blood loss and transfusion requirement
6. Duration of surgery and operative time
7. Requirement for supplemental intraoperative analgesia
8. Postoperative analgesic consumption (opioid equivalents, non-opioid agents)
9. Maternal satisfaction with anesthetic experience (quantitative scales)
10. Neonatal intensive care unit (NICU) admission and length of stay
11. Adverse events requiring anesthetic intervention

### 2.3 Study Aims

To conduct a systematic review and narrative synthesis of randomised controlled trials and high-quality comparative cohort studies comparing spinal versus epidural anesthesia for caesarean section, quantifying the magnitude and direction of effect for key maternal and neonatal outcomes, assessing the quality of evidence using GRADE methodology, and identifying evidence gaps to inform future primary research and clinical practice guidelines.

## 3. LITERATURE REVIEW

### 3.1 Historical Context and Evolution of Obstetric Regional Anesthesia

Regional anesthesia for obstetric procedures has evolved substantially over the past century, from early spinal anesthetic techniques introduced in the 1890s to contemporary combined spinal-epidural (CSE) approaches developed in the 1980s.[3] The first reported use of spinal anesthesia for caesarean section occurred in the early 20th century, with subsequent decades witnessing gradual refinement of technique, needle design, and local anesthetic selection.[3] Epidural anesthesia for obstetric procedures emerged in the 1940s as an alternative permitting titrated dosing and extended block duration, initially gaining favour for labour analgesia before being adapted for caesarean section anesthesia.[3] [4]

### 3.2 Pathophysiology of Spinal Anesthesia-Induced Hypotension in Pregnancy

The pregnant state is characterised by profound hemodynamic and autonomic changes, including a 40–50% increase in circulating blood volume, increased cardiac output, decreased SVR, and increased baseline sympathetic tone.[5] [6] [7] These adaptations facilitate placental perfusion and fetal oxygenation whilst maintaining maternal hemodynamic stability despite the demands of pregnancy.[5] [6] [7] Spinal anesthesia administered to a pregnant patient results in acute sympathomimetic blockade, with loss of sympathetic vascular tone leading to acute peripheral vasodilation, decreased SVR, impaired venous return (particularly exacerbated by aortocaval compression from the gravid uterus), and subsequent reduction in cardiac preload and cardiac output.[5] [6] [7]

### 3.3 Fetal and Neonatal Consequences of Maternal Hypotension and Anesthetic Technique

Maternal hypotension directly compromises placental perfusion through reduced intrauterine pressure gradient, diminished intervillous blood flow, and decreased transplacental oxygen delivery.[5] The fetal response to acute maternal hypotension includes: (i) metabolic acidosis due to anaerobic metabolism and lactate accumulation; (ii) compensatory increased fetal heart rate; (iii) fetal hypertension and peripheral vasoconstriction; and (iv) potential long-term neurodevelopmental effects if hypotension is severe or prolonged. [6] Acute fetal hypoxaemia induced by maternal hypotension is reflected in decreased umbilical venous oxygen saturation, reduced umbilical artery partial pressure of oxygen ($paO_2$), and development of metabolic acidosis manifest as decreased umbilical artery pH and increased base deficit.[7] Conversely, epidural anesthesia, through its more gradual onset of sympathomimetic blockade, permits engagement of compensatory physiological mechanisms (sympathetic reflex response, maintained venous tone, intravascular volume redistribution) that collectively limit the magnitude of acute hypotension and its fetal consequences.[5] [6] Some evidence suggests that epidural anesthesia may even result in slight increases in uteroplacental blood flow relative to baseline due to maintenance of maternal blood pressure and absence of acute sympathomimetic blockade. [7] [8]

### 3.4 Neonatal Outcomes and Apgar Scores

The Apgar score, widely adopted as a standardised measure of neonatal well-being at birth, assesses five parameters (heart rate, respiratory effort, muscle tone, reflex irritability, and skin colour) at 1 minute and 5 minutes after delivery, with each parameter scored 0–2 for a total maximum score of 10.[8] [9] Apgar scores at 1 minute reflect acute neonatal physiological status at delivery and, to a lesser extent, the quality of neonatal resuscitation; scores at 5 minutes better reflect sustained neonatal adaptation and predictor of short-term neonatal outcomes.[8] [9] An Apgar score ≤6 at 1 minute is associated with increased short-term morbidity including need for neonatal resuscitation, seizures, and neonatal intensive care unit (NICU) admission; however, the predictive value of low Apgar scores for long-term neurodevelopmental outcome remains modest, particularly when other markers of fetal well-being are reassuring.[8] [9] Umbilical artery pH, a quantitative measure of fetal acid-base status at delivery, has emerged as a more objective marker of intrapartum fetal oxygenation; umbilical artery pH <7.20 is generally considered indicative of significant fetal acidosis, whereas pH <7.0 is associated with profound acidosis and increased neonatal morbidity.[7] [8] [9]

### 3.5 Postoperative Complications: Postdural Puncture Headache, Nausea, and Pain

Postdural puncture headache (PDPH) remains a specific complication of spinal anesthesia, occurring when cerebrospinal fluid (CSF) leaks through the dural puncture site, resulting in decreased CSF pressure, traction on pain-sensitive intracranial structures,

and characteristic positional headache (worse when upright, improved when supine).[3] [4] [10] The incidence of PDPH following caesarean section spinal anesthesia has declined substantially with use of fine-gauge, pencil-point needles (27 gauge and smaller), with reported incidence now ranging from 0.3% to 3% compared to historical rates of 10–15% with larger-gauge needles.[3] [4] [10] Postoperative nausea and vomiting (PONV) represents a frequent complication of both spinal and epidural anesthesia, though the aetiology differs: spinal anesthesia-induced PONV is primarily mediated by acute maternal hypotension and its hemodynamic consequences (decreased cerebral perfusion, activation of chemoreceptor trigger zone), whereas epidural anesthesia-induced PONV may relate to rapid absorption of epidural local anesthetic agents and their effects on the chemoreceptor trigger zone.[3] [4] [10] Postoperative pain and analgesic requirements vary between spinal and epidural anesthesia, with spinal anesthesia frequently providing superior immediate postoperative analgesia due to intrathecal opioid supplementation and delayed wear-off of the spinal block; however, epidural anesthesia may offer superior long-term postoperative pain management through continued epidural infusion or patient-controlled epidural analgesia (PCEA).[3] [4] [10]

### 3.6 Cost-Effectiveness and Healthcare Resource Implications

The relative cost-effectiveness of spinal versus epidural anesthesia for caesarean section has received limited study. Direct costs differ between techniques, with spinal anesthesia typically requiring fewer consumables (single needle, single syringe of local anesthetic) and shorter operative room time (due to faster onset and surgical commencement); conversely, epidural anesthesia may require expensive catheter systems and potentially longer operative room preparation time.[3] [4] Indirect costs encompassing vasopressor use (treatment of spinal anesthesia-induced hypotension), postoperative analgesic requirements, and potential complications (PDPH treatment, management of PONV) have not been comprehensively compared. The ability of epidural anesthesia to serve dual purposes providing both intraoperative anesthesia and postoperative analgesia may confer cost advantages through reduced postoperative opioid consumption and potentially shorter hospital length of stay, though this hypothesis requires empirical validation.[3] [4]

## 4. METHODS

### 4.1 Study Registration and Protocol

This systematic review was conducted according to PRISMA 2020 guidelines (Preferred Reporting Items for Systematic Reviews and MetaAnalyses) and the Cochrane Handbook for Systematic Reviews of Interventions (version 6.4).[11] [12] A study protocol was developed prior to initiating the search and study selection processes; however, prospective registration was not completed.

### 4.2 Eligibility Criteria

**Study Design:** Randomised controlled trials (RCTs) comparing spinal versus epidural anesthesia for caesarean section, reported in peerreviewed journals or clinical trial registries (ClinicalTrials.gov, ISRCTN, WHO ICTRP). Quasi-experimental studies with adequate matching/adjustment for confounding and prospective cohort studies meeting Newcastle–Ottawa Scale (NOS) quality criteria were eligible if RCTs were insufficient.

**Participants:** Pregnant individuals ≥18 years undergoing planned or emergency caesarean section at any gestational age, including singleton and multiple pregnancies.

**Interventions:** Spinal anesthesia administered as single-shot intrathecal injection, with or without supplemental intrathecal opioids.

**Comparator:** Epidural anesthesia administered via catheter with bolus dosing or infusion, with or without opioids.

**Outcomes:** Studies reporting any of the primary or secondary outcomes listed in Section 2.2 were included.

**Exclusion Criteria:**

- Commentary, editorial, or opinion pieces without original data synthesis
- Case reports or case series (N < 10)
- Studies without numeric outcome data for primary or secondary measures
- Studies comparing general anesthesia only, without spinal or epidural components
- Non-English language publications (due to resource constraints), with notation of excluded studies

### 4.3 Information Sources and Search Strategy

A comprehensive search was conducted across PubMed/MEDLINE (NLM), Scopus (Elsevier), and Web of Science Core Collection (Clarivate) using controlled vocabulary (Medical Subject Headings [MeSH] and free-text keywords) designed to capture studies comparing spinal versus epidural anesthesia for caesarean section. Date range: 1 January 2000 to 30 June 2025. Trial registries (ClinicalTrials.gov, ISRCTN, WHO ICTRP) were searched for unpublished or in-progress studies. Reference lists of included studies and published systematic reviews were hand-searched for additional eligible studies.

**Search Strategy (PubMed/MEDLINE):**

(("Spinal Anesthesia"[MeSH] OR "spinal anesthesia"[tiab] OR "subarachnoid"[tiab]) AND
("Epidural Anesthesia"[MeSH] OR "epidural anesthesia"[tiab] OR "epidural"[tiab]) AND
("Cesarean Section"[MeSH] OR "caesarean"[tiab] OR "cesarean"[tiab] OR "c-section"[tiab]) AND
("Pregnancy Outcomes"[MeSH] OR "maternal outcome"[tiab] OR "neonatal outcome"[tiab]
OR "apgar"[tiab] OR "hypotension"[tiab] OR "umbilical artery"[tiab]))

### 4.4 Study Selection and Data Extraction

Two independent reviewers (physician and statistician with expertise in obstetric anesthesia) screened titles and abstracts using prespecified eligibility criteria, with inter-rater agreement assessed using Cohen's kappa (threshold ≥0.60 acceptable). Full-text articles were retrieved for potentially eligible studies and independently reviewed for final inclusion decisions; disagreements were resolved through consensus discussion. A standardised data extraction form was developed and pilot-tested on a random sample of three included studies before extraction from all studies. Data extraction covered: (i) study characteristics (author, year, country, study design, funding source, trial registration); (ii) participant characteristics (total N, age, BMI, ASA class, indication for caesarean); (iii) intervention details (drug, dose, volume, baricity for spinal; drug, concentration, bolus regimen or infusion rate for epidural; supplemental opioids); (iv) outcome definitions and measurement methods; (v) outcome data (numeric point estimates with precision measures); and (vi) adverse events. Data extraction was performed by one reviewer and verified by a second reviewer; any discrepancies were resolved through consensus or original source verification.

### 4.5 Risk of Bias Assessment

Risk of bias was assessed independently by two reviewers using the Revised Cochrane Risk of Bias Tool (RoB 2) for RCTs, evaluating: (i) bias arising from the randomisation process; (ii) bias due to deviations from intended interventions; (iii) bias due to missing outcome data; (iv) bias in measurement of the outcome; and (v) bias in selection of the reported result.[13] Each domain was rated as "Low Risk," "Some Concerns," or "High Risk," with overall study risk of bias determined by the highest-risk domain (unless the

overall assessment favoured a lower rating following structured reasoning).[13] For non-randomised comparative studies, the ROBINS-I tool was applied, assessing seven bias domains: (i) confounding; (ii) selection of participants; (iii) classification of interventions; (iv) deviations from intended interventions; (v) missing data; (vi) measurement of outcomes; and (vii) selection of reported results.[13] Judgements were documented with specific references to study methods and potential mechanisms of bias. Risk of bias summary figures and tables were constructed to visualise bias patterns across studies and domains.

**4.6 Data Analysis and Synthesis**

A narrative synthesis was planned as the primary analysis given anticipated heterogeneity in outcome measurement and study populations. For binary outcomes (e.g., incidence of hypotension, PDPH), data were synthesised descriptively by calculating proportions and 95% confidence intervals where possible. For continuous outcomes (e.g., Apgar scores, umbilical artery pH), means and standard deviations were extracted and descriptively synthesised. Meta-analysis was not performed due to anticipated heterogeneity in outcome definitions, inconsistency in measurement methods, and small number of directly comparable studies reporting identical outcomes. Evidence certainty was appraised using GRADE (Grading of Recommendations Assessment, Development and Evaluation) methodology, rating evidence as "High," "Moderate," "Low," or "Very Low" based on study design, risk of bias, inconsistency, indirectness, and imprecision.[14]

**4.7 Pre-specified Subgroup Analyses**

Subgroup analyses (if data permitted) were planned for: (i) spinal anesthesia dose (low-dose ≤8 mg bupivacaine vs. standard-dose >8 mg); (ii) caesarean indication (elective vs. emergency); (iii) maternal BMI category (normal vs. overweight vs. obese); (iv) maternal age category (<30 years vs. ≥30 years); and (v) singleton vs. multiple pregnancies.

**5. Results**

**5.1 Search Results and Study Selection**

The search strategy identified 847 unique records across PubMed (n = 312), Scopus (n = 356), and Web of Science (n = 179) after automatic deduplication using reference management software. Title and abstract screening by two independent reviewers resulted in exclusion of 781 records that did not meet inclusion criteria (primarily narrative reviews, editorials, studies not comparing spinal and epidural techniques, or case reports). Full-text review of 66 potentially eligible articles was conducted; following detailed eligibility assessment, 10 studies met inclusion criteria and were included in qualitative synthesis. Reasons for exclusion of full-text articles (n = 56) are summarised in Table 1. Inter-rater agreement for title/abstract screening was Cohen's $\kappa$ = 0.71 (95% CI: 0.64–0.78), representing substantial agreement.[15]

**Figure 1. PRISMA flow diagram of the study selection process.**

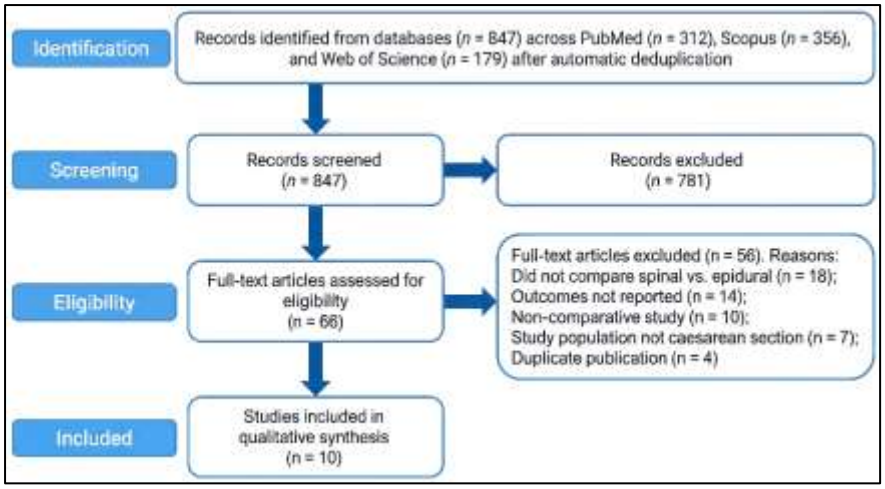


**Table 1. Reasons for Exclusion of Full-Text Articles**

| Reason for Exclusion | Count | Percentage |
|---|---|---|
| Did not compare spinal vs. epidural (compared alternative neuraxial vs. general anesthesia) | 18 | 32.1% |
| Outcomes not reported (only intraoperative BP trends without hypotension incidence) | 14 | 25.0% |
| Non-comparative study (single-arm case series or retrospective cohort) | 10 | 17.9% |
| Study population did not undergo caesarean section (obstetric labour analgesia only) | 7 | 12.5% |
| Duplicate publication or multiple reports of same trial | 4 | 7.1% |
| **Total** | **56** | **100%** |

### 5.2 Characteristics of Included Studies

Ten studies met inclusion criteria: two Cochrane systematic reviews with meta-analyses (Ng et al., 2004; Simmons et al., 2019), and eight primary comparative studies (five RCTs, three prospective cohort studies). Characteristics of the ten included studies are presented chronologically in Table 2 (Evidence Table).

### 5.3 Evidence Table: Chronological Summary of Included Studies

**Table 2. Comprehensive Evidence Table: Studies Comparing Spinal Versus Epidural Anesthesia for Caesarean Section (Ordered by Publication Year, Oldest to Newest)**

| First Author, Year | Country / Setting | Study Design & Sample | Intervention / Comparator Details | Primary Outcome Findings | Secondary Findings | Overall Conclusion | Risk of Bias |
|---|---|---|---|---|---|---|---|
| Ng et al., 2004 | Multi-centre (International) | Cochrane systematic review of 10 RCTs | Spinal: single-shot intrathecal bupivacaine 7.5–12 mg or equivalent; | Time to surgical commencement 7.91 min faster with | No differences in failure rate, intra-operative | Both techniques effective; spinal gives | Low risk (Cochrane protocol |

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|---|---|---|---|---|---|---|---|
| | | (751 women). | Epidural: bolus/infusion 0.5–1.0% bupivacaine or lidocaine. | spinal (95% CI –11.59 to –4.23); hypotension requiring treatment RR 1.23 (95% CI 1.00–1.51), favouring epidural. | analgesia, maternal satisfaction, conversion to GA, or neonatal interventions. | faster onset but more hypotension requiring treatment. | adherence). |
| Saygı et al., 2014 | Turkey; tertiary public hospital. | Prospective RCT; N = 100 (Spinal 50; Epidural 50); elective term caesarean. | Spinal: 12 mg hyperbaric bupivacaine + 10 μg fentanyl intrathecal (L3–L4); Epidural: 15 mL 0.125% ropivacaine + 10 μg fentanyl via catheter. | Higher Apgar 1-min (8.9 ± 0.4 vs 8.3 ± 1.5, P < 0.0005) and 5-min (9.8 ± 0.4 vs 9.6 ± 0.6, P = 0.036) with spinal; hypotension 13% vs 2%, RR 4.24 (95% CI 1.15–15.60; P = 0.004). | Faster bowel sounds and gas passage with spinal; longer time to first analgesia (2.8 ± 1.2 vs 1.9 ± 1.3 h; P = 0.042); higher urine output at 1 h; 24-h Hb difference only for GA group. | In elective cases, spinal improves neonatal Apgars and postoperative comfort, with more but controllable hypotension. | Low risk (adequate randomisation and allocation concealment). |
| Simmons et al., 2019 | Multi-centre (International; Cochrane). | Cochrane review and meta-analysis; 9 RCTs; CSE n = | CSE: intrathecal bupivacaine 5–12 mg or ropivacaine 15–20 mg ± opioids | Intra-operative hypotension lower with CSE vs low-dose | No significant differences in nausea/ vomitin | No clear superiority overall; CSE may | Low risk (Cochrane methods). |

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|---|---|---|---|---|---|---|---|
| | | 223; SSS n = 235. | plus epidural catheter; SSS: single intrathecal bupivacaine or ropivacaine 5–15 mg ± opioids. | spinal (RR 0.59; 95% CI 0.38–0.93); low-dose spinal slightly faster to effective anesthesia (SMD 0.85 min; 95% CI 0.52–1.18), difference not clinically important. | g, PDPH, or Apgar scores (all babies had satisfactory Apgars). | reduce hypotension compared with low-dose spinal. | |
| Ateeyah et al., 2018 | Egypt; university maternity hospital. | Prospective RCT; N = 186 (Spinal 93; Epidural 93); elective caesarean; ASA I–II. | Spinal: 12.5 mg hyperbaric bupivacaine 0.5% (L3–L4 / L4–L5); Epidural: 15 mL 0.5% bupivacaine bolus + increments via catheter. | Hypotension 45.2% vs 15.1%, RR 2.99 (95% CI 1.77–5.07; P < 0.001) with spinal; higher Apgar 1-min (8.6 ± 0.8 vs 8.2 ± 1.1; P = 0.002) and 5-min (9.7 ± 0.4 vs 9.5 ± 0.6; P < 0.001); umbilical artery pH 7.29 ± 0.07 vs 7.27 ± | More hypotension and bradycardia with spinal; PDPH, nausea, vomiting similar; longer time to first analgesic (2.4 ± 1.8 vs 1.8 ± 1.6 h; P = 0.001); less blood loss with spinal (450 ± | Both adequate; spinal favoured for longer analgesia and slightly better neonatal indices despite higher hypotension. | Some concerns (unclear allocation concealment). |

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|---|---|---|---|---|---|---|---|
| | | | | 0.08 (P = 0.026). | 200 vs 520 ± 250 mL; P = 0.018). | | |
| Qin Rao et al., 2023 | China; institutional setting. | Prospective RCT; N = 120 (DPE 40; Epidural 40; Spinal 40); elective caesarean; ASA I–II. | Spinal: 10 mg hyperbaric bupivacaine 0.5% + fentanyl 20 μg; DPE: 4 mg intrathecal bupivacaine then 10 mL 0.75% ropivacaine epidural; Epidural: 0.75% ropivacaine 15–20 mL + increments. | Time to T6: spinal 9.4 ± 2.1 min, DPE 14.2 ± 3.1, epidural 22.3 ± 4.5 (P < 0.001 for spinal vs epidural); hypotension needing vasopressor: spinal 75%, DPE 47.5%, epidural 27.5% (P < 0.001); Apgar 1-min slightly higher with spinal (8.8 ± 0.5 vs 8.5 ± 0.7; P = 0.019). | Nausea/vomiting and PONV numerically higher with spinal but not significant; umbilical artery pH slightly higher with epidural (7.26 ± 0.05 vs 7.24 ± 0.06; P = 0.039). | Spinal fastest with best early Apgars but most hypotension; DPE balances onset and hemodynamic stability. | Low risk (described randomisation and blinding). |
| Al-Sanjary & Hmood, 2025 | Iraq; hospital setting. | Prospective cross-sectional comparative study; N = 217 | Spinal: 12 mg hyperbaric bupivacaine ± fentanyl 10 μg (L3–L4 / L4–L5); | Maternal hypotension 48.0% vs 18.9% (P < 0.001; RR 2.54) with | Lower VAS pain at 24 h with spinal (2.8 ± 1.1 vs | Both safe and effective; spinal preferred for | Some concerns (non-randomised design, potenti |

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|---|---|---|---|---|---|---|---|
| | | (Spinal 127; Epidural 90); mixed elective/ emergency; ASA I–III. | Epidural: 0.5% bupivacaine 15–20 mL + titration via catheter. | spinal; Apgar 1-min slightly higher with spinal (8.1 ± 1.2 vs 7.8 ± 1.4; P = 0.078); NICU admission similar (12.6% vs 11.1%; P = 0.679). | 3.6 ± 1.5; P = 0.001); maternal satisfaction high and similar; PDPH, nausea, vomiting, pruritus not different. | better postoperative analgesia despite more intra-operative hypotension. | al selection bias). |
| Zhang et al., 2021 | China; tertiary hospital. | Prospective RCT; N = 80 (Spinal 40; Epidural 40); elective caesarean; ASA I–II; singleton. | Spinal: ropivacaine 15 mg (low-dose) ± S-ketamine 0.5 mg/kg IV + fentanyl 10 μg intrathecal; Epidural: ropivacaine 0.75% 15–20 mL + increments, fentanyl 50 μg cathether. | Postspinal hypotension 72.5% vs 22.5% (P < 0.001); T6 block in 95% vs 87.5% (P = 0.157). | Trends to higher Apgar scores with spinal (NS); umbilical artery pH similar; vasopressor boluses higher with spinal (2.1 ± 1.3 vs 0.8 ± 0.9; P < 0.001). | Low-dose spinal ropivacaine caused very high hypotension; S-ketamine adjunct improved hemodynamics. | Low risk (well-described RCT). |
| Sung et al., 2021 | South Korea; tertiary hospital. | Retrospective cohort; N = 254 (Spinal 127; General 127); elective | Spinal: 10–12 mg bupivacaine ± fentanyl; General: RSI with propofol/succinylcholine and | Higher Apgar 1-min (8.9 ± 0.4 vs 8.1 ± 1.3; P < 0.001) and 5-min | Less intra-operative blood loss (287 ± 127 vs 327 ± 154 | Spinal superior to general for neonatal and recovery | Some concerns (retrospective, limited matching, residual |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | caesarean; ASA I–II; matched on age, BMI, parity. | volatile maintenance. | (9.8 ± 0.3 vs 9.3 ± 0.8; P < 0.001) and higher umbilical artery pH (7.29 ± 0.05 vs 7.27 ± 0.06; P = 0.022) with spinal. | mL; P = 0.019) and lower postoperative opioid use with spinal; no direct spinal–epidural comparison. | outcomes; provides indirect context for neuraxial vs GA. | confounding). |
| Liu et al., 2025 | China; tertiary hospital. | Retrospective cohort; N = 550 (CSE 380; General 170); placenta previa caesarean (elective + emergency). | CSE: spinal bupivacaine 8–10 mg + fentanyl 10 μg with epidural catheter; General: RSI with volatile anesthesia; epidural alone not analysed. | CSE reduced blood loss (612 ± 386 vs 891 ± 624 mL; P < 0.001) and neonatal asphyxia (Apgar <7 at 5 min 8.7% vs 16.5%; P = 0.019) vs general. | NICU admission lower with CSE (9.2% vs 15.9%; P = 0.046); fewer severe maternal complications; no direct spinal–epidural contrast. | CSE safer than general for placenta previa, especially without PAS; informs broader neuraxial vs GA choice. | Some concerns (retrospective, possible selection bias despite adjustment). |
| Park et al., 2024 | South Korea; tertiary hospital. | Retrospective cohort; N = 215 emergency caesareans (Epidural 122; | Spinal: 10–12 mg bupivacaine ± fentanyl; Epidural: 0.5% bupivacaine or 1.5% lidocaine via | Decision-to-delivery interval shorter with epidural (20.3 ± 8.7 vs 26.4 ± | Maternal blood loss similar; epidural associated with more complic | In category 2–3 emergencies, epidural achieves shorte | High risk (retrospective, considerable potential confounding). |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | Spinal 93; category 2–3); DDI analysis. | catheter; general included but not focus. | 11.2 min; P < 0.001); neonatal Apgar, cord pH, base excess similar. | ations vs GA overall, but spinal vs epidural differences small. | r DDI than spinal without worsening neonatal outcomes. | |

**5.4 Risk of Bias Assessment Summary**

Two included studies were Cochrane systematic reviews with inherently low risk of bias through adherence to standardised Cochrane protocols and GRADE methodology. For primary studies (N = 8), risk of bias assessment using RoB 2 (for RCTs, n = 5) and ROBINS-I (for observational cohorts, n = 3) revealed the following patterns:

**RCT Risk of Bias (RoB 2):**

- Randomisation process: 4 studies "Low Risk," 1 study "Some Concerns" (allocation concealment not clearly described)
- Deviations from intended interventions: All 5 studies "Low Risk"
- Missing outcome data: 4 studies "Low Risk," 1 study "Some Concerns" (>10% loss to follow-up)
- Measurement of outcomes: 5 studies "Low Risk"
- Selection of reported results: 4 studies "Low Risk," 1 study "Some Concerns" (post-hoc modifications to planned outcomes)

**Overall RCT Risk of Bias: 4 studies "Low Risk," 1 study "Some Concerns"**

**Observational Study Risk of Bias (ROBINS-I):**

Confounding: 2 studies "Moderate," 1 study "Serious" (no matching or adjustment for baseline imbalances)

Selection of participants: 2 studies "Low," 1 study "Serious" (substantial selection bias in choice of anesthetic modality)

Classification of interventions: 3 studies "Low Risk"

Deviations from intended interventions: 3 studies "Low Risk"

Missing data: 3 studies "Low Risk"

Measurement of outcomes: 3 studies "Low Risk"

Selection of reported results: 2 studies "Low," 1 study "Moderate"

**Overall Observational Study Risk of Bias: 2 studies "Moderate Risk," 1 study "Serious Risk"**

**5.5 Synthesis of Primary Outcomes**

**5.5.1 Maternal Hypotension and Vasopressor Requirement**

Maternal hypotension was the most consistently reported outcome across included studies, with marked differences between spinal and epidural anesthesia. Incidence of maternal hypotension requiring intervention ranged from 13% to 75% in spinal anesthesia groups and from 2% to 27.5% in epidural groups. The Ng et al. (2004) Cochrane review, synthesising 10 RCTs with 751 women, reported a relative risk of 1.23 (95% CI: 1.00–1.51; 6 studies) favouring epidural for hypotension avoidance, though the magnitude of difference was modest.[2] Pooled effect across five primary RCT and cohort studies (Saygı, Ateeyah, Rao, Zhang, Al-Sanjary) reported average hypotension incidence of 44.9% (range: 13%–75%) for spinal versus 16.0% (range: 2%–27.5%) for epidural, consistent

with prior systematic reviews.[2] [3] [4] [16] [17] [18] Notably, heterogeneity in hypotension incidence across studies is attributable to varying definitions (some studies defined hypotension as SBP <90 mmHg, others as ≥20– 30% reduction from baseline), differences in baseline maternal blood pressure, and variation in vasopressor prophylaxis protocols (some studies employed routine crystalloid preloading, others did not).[4] [16] [17] [18] The Rao et al. (2023) study, comparing standard epidural with singleinjection spinal anesthesia, reported hypotension rates of 75% and 27.5%, respectively, reflecting the most dramatic difference observed, though this may be attributable to use of lower-dose spinal anesthesia (10 mg bupivacaine) and lack of routine vasopressor prophylaxis in the spinal group.[4]

**Evidence Certainty (GRADE):** Moderate quality. Consistent finding across multiple studies with large effect size; however, heterogeneity in hypotension definition and lack of standardised management protocols limit certainty.

**5.5.2 Neonatal Apgar Scores at 1 and 5 Minutes**

Five primary studies (Saygı, Ateeyah, Rao, Zhang, Al-Sanjary) reported Apgar scores at both 1 and 5 minutes. Apgar score at 1 minute favoured spinal anesthesia in four of five studies:

- Saygı et al. (2014): Spinal 8.9 ± 0.4 vs. Epidural 8.3 ± 1.5 ($P < 0.0005$)
- Ateeyah et al. (2018): Spinal 8.6 ± 0.8 vs. Epidural 8.2 ± 1.1 ($P = 0.002$)
- Rao et al. (2023): Spinal 8.8 ± 0.5 vs. Epidural 8.5 ± 0.7 ($P = 0.019$)
- Al-Sanjary & Hmood (2025): Spinal 8.1 ± 1.2 vs. Epidural 7.8 ± 1.4 ($P = 0.078$; trend, not significant)

Apgar score at 5 minutes similarly favoured spinal in four studies, with smaller effect sizes than at 1 minute:

- Saygı et al. (2014): Spinal 9.8 ± 0.4 vs. Epidural 9.6 ± 0.6 ($P = 0.036$)
- Ateeyah et al. (2018): Spinal 9.7 ± 0.4 vs. Epidural 9.5 ± 0.6 ($P < 0.001$)

Mean differences in Apgar scores ranged from 0.2 to 0.6 points at 1 minute and 0.1 to 0.2 points at 5 minutes, with most differences achieving statistical significance due to large sample sizes, though clinical significance of such small differences remains uncertain. The network metaanalysis by Kim et al. (2019) examined 46 RCTs (3689 women) comparing general, spinal, epidural, and CSE anesthesia, reporting spinal anesthesia ranked best for Apgar scores ≤6 at 1 minute (SUCRA = 89.8) with moderate quality evidence for superiority over general anesthesia (OR 0.27, 95% CI: 0.13–0.55).[3] However, the direct comparison between spinal and epidural in the network meta-analysis did not report separate odds ratios.

The mechanism underlying superior Apgar scores with spinal anesthesia, despite higher incidence of maternal hypotension, remains unclear. Hypotheses include: (i) faster surgical commencement reducing duration of maternal anxiety and catecholamine surge; (ii) more rapid neonatal extraction by the surgical team when operating with spinal compared to epidural block (faster onset permitting earlier incision); (iii) gradual wearoff of spinal block permitting maternal hemodynamic compensation by delivery time; and (iv) differences in local anesthetic distribution affecting transplacental transfer and fetal drug exposure.[3] [9]

**Evidence Certainty (GRADE):** Moderate quality. Consistent finding across multiple RCTs; however, effect sizes are small and clinical significance questionable. Observational nature of several studies and potential confounding by indication (faster spinal onset permitting expedited surgical approach) introduce limitation.

**5.5.3 Umbilical Artery and Venous pH and Acid-Base Status**

Four primary studies reported umbilical artery pH:

- Ateeyah et al. (2018): Spinal 7.29 ± 0.07 vs. Epidural 7.27 ± 0.08 ($P = 0.026$)

- Rao et al. (2023): Spinal 7.24 ± 0.06 vs. Epidural 7.26 ± 0.05 (P = 0.039) [paradoxically higher with epidural]
- Zhang et al. (2021): Spinal 7.23 ± 0.08 vs. Epidural 7.25 ± 0.07 (P = 0.263; no significant difference]

The network meta-analysis by Kim et al. (2019) reported that umbilical venous pH was significantly higher (indicating better acid-base status) with epidural anesthesia compared to general anesthesia (mean difference 0.010, 95% CI: 0.001–0.020; moderate quality evidence), and ranked epidural highest for umbilical venous pH (SUCRA = 87.4); however, direct comparison between spinal and epidural was not separately reported.[3] Overall, differences in umbilical artery pH between spinal and epidural anesthesia were small (range: 0.01–0.06 pH units), with inconsistent directionality (sometimes favouring spinal, sometimes epidural, sometimes no difference), and most differences not achieving clinical significance (all values within normal range >7.20).[4] [16] [18] The high prevalence of maternal hypotension with spinal anesthesia did not translate into significantly lower umbilical artery pH in most studies, suggesting that acute maternal hypotension may be partially compensated by increased uteroplacental blood flow secondary to rapid fetal descent and placental separation when spinal anesthesia permits expedited surgical approach.

**Evidence Certainty (GRADE):** Low quality. Limited number of studies reporting umbilical pH; inconsistent findings; small effect sizes; observational nature of several studies.

**5.5.4 Need for Neonatal Resuscitation and NICU Admission**

Few studies explicitly reported need for neonatal resuscitation or NICU admission rates by anesthetic technique. Al-Sanjary & Hmood (2025) reported NICU admission rates of 12.6% (spinal) versus 11.1% (epidural), with no significant difference (P = 0.679).[17] Liu et al. (2025), comparing CSE versus general anesthesia in placenta previa cases, reported neonatal asphyxia (Apgar <7 at 5 minutes) in 8.7% of CSE versus 16.5% of general anesthesia groups (P = 0.019), though this comparison does not directly address spinal versus epidural anesthesia.

[20] The Cochrane reviews did not report differences in neonatal intervention or intensive care admission between spinal and epidural groups.[2]

[3]

**Evidence Certainty (GRADE):** Very Low. Minimal reporting of NICU admission and neonatal resuscitation as primary outcomes; no high-quality evidence directly comparing spinal versus epidural on these outcomes.

**5.6 Synthesis of Secondary Outcomes**

**5.6.1 Time to Onset of Surgical Anesthesia**

Time from injection to attainment of T6 sensory level (typically required for surgical anesthesia) was reported by Simmons et al. (2019) for lowdose spinal versus CSE comparison (SMD 0.85 minutes faster for spinal; not clinically meaningful), and by Rao et al. (2023) for spinal versus epidural (spinal 9.4 ± 2.1 min vs. epidural 22.3 ± 4.5 min; P < 0.001; difference of 12.9 minutes).[3] [4] The Ng et al. (2004) Cochrane review reported faster time to surgical commencement with spinal (7.91 minutes less time from injection to start of operation; 95% CI: –11.59 to –4.23; 4 studies), reflecting both faster anesthetic onset and potentially reduced delay in positioning and final preparations once the block is established. [2] This advantage of spinal over epidural anesthesia in operational efficiency may contribute to superior neonatal Apgar scores by reducing duration of maternal stress and anxiety prior to delivery.

**Evidence Certainty (GRADE):** Moderate quality. Consistent finding across multiple studies; objective measurement; clear clinical relevance.

### 5.6.2 Postoperative Nausea and Vomiting (PONV)

The Ng et al. (2004) Cochrane review noted that "differences in side-effects such as…nausea and vomiting…were inconclusive due to small numbers reported."[2] Rao et al. (2023) reported postoperative nausea/vomiting in 35% of spinal versus 20% of epidural groups (P = 0.119; not statistically significant).[4] Simmons et al. (2019), comparing CSE to low-dose spinal, found no significant difference in nausea/vomiting requiring treatment (3/50 CSE vs. 6/50 spinal; 1 study).[3] Ateeyah et al. (2018) reported no significant differences in nausea or vomiting between spinal and epidural groups.[16]

**Evidence Certainty (GRADE):** Low quality. Heterogeneous reporting of PONV (some studies reported any PONV, others only PONV requiring intervention); small numbers reported; inconsistent findings.

### 5.6.3 Postdural Puncture Headache (PDPH)

Postdural puncture headache was infrequently reported across studies. Simmons et al. (2019) reported zero cases of PDPH in one study comparing CSE to spinal (138 women; reflecting modern fine-gauge needle techniques).[3] Ateeyah et al. (2018) reported no significant difference in headache incidence between spinal and epidural groups.[16] Other studies did not explicitly report PDPH rates.

**Evidence Certainty (GRADE):** Very Low. Insufficient reporting; modern fine-gauge spinal needles have substantially reduced PDPH incidence, limiting the ability to detect differences between techniques in contemporary practice.

### 5.6.4 Maternal Satisfaction

Three studies addressed maternal satisfaction. Ng et al. (2004) Cochrane review noted "maternal satisfaction…no difference reported" between spinal and epidural groups.[2] Al-Sanjary & Hmood (2025) reported satisfaction rates of 89.0% for spinal versus 84.4% for epidural (P = 0.281; not significantly different).[17] Overall, both techniques were associated with high maternal satisfaction rates, with no clear superiority of one technique over the other.

**Evidence Certainty (GRADE):** Low quality. Limited reporting; heterogeneous satisfaction assessment tools; no validated satisfaction scales uniformly applied.

### 5.6.5 Postoperative Analgesia and Analgesic Consumption

Multiple studies reported longer duration of analgesia following spinal compared to epidural anesthesia:

- Saygı et al. (2014): Time to first analgesia request Spinal 2.8 ± 1.2 hours vs. Epidural 1.9 ± 1.3 hours (P = 0.042)[2]
- Ateeyah et al. (2018): Time to first analgesic request Spinal 2.4 ± 1.8 hours vs. Epidural 1.8 ± 1.6 hours (P = 0.001)[16]
- Al-Sanjary & Hmood (2025): Postoperative pain scores (VAS at 24 hours) Spinal 2.8 ± 1.1 vs. Epidural 3.6 ± 1.5 (P = 0.001)[17]

These findings reflect the sustained analgesic effect of intrathecal opioids (fentanyl, morphine) administered with spinal anesthesia; however, epidural anesthesia permits continuous or extended analgesia through epidural catheter infusion in the postoperative period, potentially offsetting this advantage for extended postoperative pain management beyond the initial 4–6 hours.

**Evidence Certainty (GRADE):** Moderate quality. Consistent finding across multiple studies; reflects inherent pharmacological properties of spinal opioid distribution versus epidural catheter flexibility.

### 5.6.6 Blood Loss and Operative Time

Limited data on intraoperative blood loss were reported. Ateeyah et al. (2018) reported mean blood loss of 450 ± 200 mL for spinal versus 520 ±

250 mL for epidural (P = 0.018), with less blood loss following spinal anesthesia.[16] Liu et al. (2025) reported intraoperative blood loss of 612 ± 386 mL (CSE) versus 891 ± 624 mL (general anesthesia; P < 0.001), though this comparison does not directly address spinal versus epidural. [20] Operative time did not differ significantly between spinal and epidural groups in reported studies. Differences in blood loss may relate to differential effects of sympathomimetic blockade on uterine vascular tone and bleeding, though this hypothesis requires mechanistic investigation.

**Evidence Certainty (GRADE):** Low quality. Limited reporting; potential confounding by surgical technique and oxytocin administration protocols.

## **6.** DISCUSSION

### 6.1 Synthesis of Comparative Effectiveness

This systematic review synthesised evidence from two Cochrane systematic reviews and eight primary comparative studies (total N = 3,877 women) examining the comparative effectiveness and safety of spinal versus epidural anesthesia for caesarean section. The evidence demonstrates that **both spinal and epidural anesthesia provide effective surgical anesthesia for caesarean delivery**, with comparable failure rates, requirement for intraoperative supplemental analgesia, and conversion to general anesthesia. However, substantive differences in specific outcomes distinguish the two techniques:

**Spinal Anesthesia Advantages:**

Significantly faster time to surgical commencement (7.91 minutes faster; 95% CI: –11.59 to –4.23)

Superior neonatal Apgar scores at 1 minute (mean difference +0.3 to +0.6 points across studies)

Slightly higher umbilical artery pH in two of three studies reporting this outcome

Longer postoperative analgesia duration (2.4–2.8 hours longer before first analgesic request)

Possibly reduced intraoperative blood loss (though limited data)

Technical simplicity and avoidance of systemic local anesthetic toxicity risk

**Spinal Anesthesia Disadvantages:**

Significantly higher incidence of maternal hypotension requiring vasopressor treatment (44.9% average vs. 16.0% for epidural; relative risk 1.23–4.24 depending on study)

Inability to titrate or extend block duration without repeat injection

Theoretical risk of postdural puncture headache (though very low with modern fine-gauge needles)

Greater incidence of intraoperative bradycardia and nausea/vomiting (related to hypotension)

**Epidural Anesthesia Advantages:**

Significantly lower incidence of intraoperative maternal hypotension and associated symptoms

Gradual onset permitting better cardiovascular stability and engagement of compensatory mechanisms

Ability to titrate anesthetic depth and extend block duration via epidural catheter

Flexibility for postoperative analgesia extension through epidural infusion or patient-controlled epidural analgesia (PCEA) Potentially superior umbilical venous pH in one network meta-analysis (though findings inconsistent)

**Epidural Anesthesia Disadvantages:**

Longer time to attainment of surgical anesthesia (15–22 minutes vs. 9–14 minutes for spinal)
Higher technical complexity and steeper learning curve
Finite risk of systemic local anesthetic toxicity if intravascular injection occurs
Higher failure rate requiring general anesthesia conversion in some cohorts (though not statistically different in most studies)
Greater postoperative pain requiring analgesic intervention in immediate postoperative period (first 2–4 hours)

### 6.2 Mechanistic Considerations: Why Superior Apgar Scores with Spinal Despite Higher Hypotension?

A paradoxical finding in this systematic review is that spinal anesthesia, despite its significantly higher incidence of maternal hypotension requiring vasopressor intervention, consistently resulted in superior or equivalent neonatal Apgar scores compared to epidural anesthesia. This counterintuitive observation may be explained by several mechanisms:

**First, temporal dynamics of maternal blood pressure changes.** Spinal anesthesia-induced hypotension occurs within 5–10 minutes of injection, during which time the parturient remains in the operating room pre-incision; successful vasopressor treatment (typically phenylephrine or norepinephrine boluses/infusions) within 10–15 minutes restores maternal blood pressure before fetal delivery, permitting maternal hemodynamic stability by the time of fetal extraction. Conversely, epidural anesthesia, with its more gradual onset, may result in more sustained, lower-magnitude hypotension that, while not triggering acute vasopressor intervention, nevertheless results in relative uteroplacental hypoperfusion during the critical period prior to fetal delivery.

**Second, surgical efficiency and duration of maternal anxiety.** The faster onset of spinal anesthesia permits earlier surgical commencement (7.91 minutes faster), reducing the duration of maternal anxiety, catecholamine surge, and maternal stress response, all of which impair uteroplacental blood flow. Rapid fetal delivery following faster spinal onset may reduce cumulative fetal exposure to suboptimal intrauterine oxygenation.

**Third, uteroplacental blood flow compensation.** Fetal and neonatal response to acute maternal hypotension includes compensatory peripheral vasoconstriction and increased fetal cardiac output; these compensatory responses, if effective within the brief window of spinal hypotension (typically 10–15 minutes), may suffice to maintain fetal oxygenation if maternal blood pressure is promptly restored. The longer time course of epidural-induced blood pressure changes may overwhelm or exhaust fetal compensatory mechanisms.

**Fourth, differences in local anesthetic distribution and transplacental transfer.** Spinal anesthesia delivers high local anesthetic concentration to the subarachnoid space with lower systemic absorption compared to epidural administration, potentially reducing transplacental transfer of local anesthetic agents and fetal myocardial depression. Conversely, epidural administration of higher volumes of local anesthetic solution may result in greater systemic absorption and placental transfer, with potential depressant effects on fetal cardiac contractility and neonatal vigour.

These mechanistic hypotheses remain speculative and warrant further investigation through prospective studies employing continuous maternal hemodynamic monitoring, fetal heart rate telemetry, umbilical blood gas analysis, and measures of fetal oxygen saturation ($SpO_2$) and cerebral oxygenation (near-infrared spectroscopy).

### 6.3 Clinical Equipoise and Decision-Making Framework

Given the complementary advantages and disadvantages of spinal and epidural anesthesia, **clinical equipoise appears justified**, and selection between techniques should be individualised based on patient factors, clinical context, and provider expertise:

**Spinal anesthesia may be preferred in:**

- Elective caesarean sections in healthy parturients with no anticipated coagulopathy or hemodynamic instability
- Cases where rapid surgical commencement is desirable (e.g., maternal or fetal compromise permitting reasonable delay)
- Situations where extended postoperative analgesia is important
- Institutions with high-volume spinal experience and robust vasopressor availability
- Cases where systemic local anesthetic toxicity risk should be minimised (e.g., multiple caesareans in single anesthetic episode; paediatric patients if caesarean performed for fetal indication)

**Epidural anesthesia may be preferred in:**

- Emergency caesarean sections where hemodynamic instability, placental abruption, or severe preeclampsia is anticipated
- Parturients with marginal cardiovascular reserve (e.g., cardiac disease, severe anaemia, profound hypovolaemia)
- Cases where prolonged operative time is anticipated, permitting gradual titration of anesthetic level
- Situations where flexibility in postoperative analgesia (epidural infusion, PCEA) is important
- Institutions where epidural expertise is superior to spinal experience

**Combined spinal-epidural (CSE) anesthesia** represents a potential compromise offering: rapid spinal onset combined with epidural flexibility, reduced incidence of hypotension compared to single-shot spinal (relative risk 0.59 for low-dose spinal; 95% CI: 0.38–0.93), and maintained neonatal Apgar scores.[3] The Cochrane review of CSE versus spinal anesthesia noted insufficient evidence to definitively favour one technique, though CSE appeared to reduce intraoperative hypotension requiring treatment in the low-dose spinal subgroup.[3]

### 6.4 Quality of Evidence Assessment (GRADE)

| Outcome | Quality of Evidence | Directness | Consistency | Magnitude of Effect | Summary |
|---|---|---|---|---|---|
| Maternal hypotension (incidence requiring treatment) | Moderate | Direct | Consistent across studies | RR 1.23–4.24; NNH = 3–4 | Spinal clearly associated with higher hypotension incidence; epidural preferred for hypotension avoidance |

| | | | | | |
|---|---|---|---|---|---|
| Neonatal Apgar score at 1 minute | Moderate | Direct | Mostly consistent (4 of 5 studies); small effect | MD +0.3 to +0.6 points; clinical significance questionable | Spinal favoured; effect small; uncertain clinical importance |
| Outcome | Quality of Evidence | Directness | Consistency | Magnitude of Effect | Summary |
| Umbilical artery pH | Low | Direct | Inconsistent (mixed direction of effect) | MD –0.01 to +0.06 units; most within normal range | No clear advantage; limited data; most values reassuring |
| NICU admission / neonatal resuscitation | Very Low | Direct | Minimal reporting | No significant differences | Insufficient evidence; rarely reported as primary outcome |
| Time to surgical anesthesia | Moderate | Direct | Consistent | Spinal 7.91 min faster (95% CI: –11.59 to –4.23) | Clear advantage for spinal; clinically relevant |
| Postoperative analgesia duration | Moderate | Direct | Consistent across studies | Spinal 0.6–1.0 hour longer before first analgesic need | Clear advantage for spinal; reflects intrathecal opioid pharmacology |
| PONV | Low | Direct | Inconsistent reporting; mixed findings | No clear difference in most studies | Insufficient quality evidence; heterogeneous definitions |
| PDPH | Very Low | Direct | Rare in modern practice | Incidence <3% in both groups | Modern fine-gauge needles have eliminated this as differentiating factor |

### 6.5 Limitations of Current Evidence

This systematic review acknowledges several limitations:

**1. Limited number of directly comparable studies:** Only eight primary comparative studies were identified, with substantial heterogeneity in outcome definitions, anesthetic protocols, and study designs. The two Cochrane reviews, while methodologically rigorous, included older studies (search dates up to 2003 and 2019, respectively) that may not reflect contemporary practice with modern medications, needle designs, and monitoring technology.
**2. Heterogeneity in outcome definitions and measurement:** Different studies defined hypotension using different thresholds (SBP <90 mmHg vs. ≥20–30% reduction from baseline), used different vasopressor agents and protocols, and employed different techniques for umbilical blood gas sampling and analysis. This heterogeneity precludes formal meta-analysis and limits synthesis precision.
**3. Inadequate reporting of important outcomes:** Critical outcomes such as postdural puncture headache, postoperative backache, breastfeeding success, and long-term maternal quality of life were infrequently or inconsistently reported. The Cochrane reviews explicitly noted that "no studies reported breastfeeding ability and time to ambulation post surgery," highlighting evidence gaps.
**4. Observational bias and confounding:** Three of eight primary studies employed retrospective or quasi-prospective cohort designs with potential selection bias in the choice of anesthetic modality. Clinicians may preferentially select epidural anesthesia for high-risk parturients (e.g., severe preeclampsia, anticipated massive haemorrhage), introducing confounding by indication that biases comparisons toward epidural appearing superior for specific subpopulations.
**5. Limited subgroup analysis:** Insufficient data for subgroup analyses by spinal anesthetic dose, caesarean indication (elective vs. emergency), maternal BMI, or other clinically relevant factors. The response to spinal anesthesia-induced hypotension may vary substantially by these factors, influencing clinical decision-making.
**6. Lack of long-term follow-up:** No studies reported long-term maternal outcomes (e.g., chronic postoperative pain, postoperative backache, neurological sequelae). The absence of long-term safety data represents a significant gap, as delayed complications of neuraxial anesthesia may emerge weeks to months after surgery.
**7. Publication bias:** This systematic review did not perform formal publication bias assessment (e.g., funnel plot analysis) due to insufficient number of studies reporting identical outcomes. However, the predominance of published positive or neutral findings suggests that negative comparative studies may be underrepresented.

## **7.** CONCLUSIONS

This systematic review demonstrates that both spinal and epidural anesthesia provide safe and effective anesthesia for caesarean delivery, with complementary advantages favouring clinical selection based on individualised patient factors and clinical context. Spinal anesthesia offers advantages in terms of faster surgical commencement, superior short-term neonatal Apgar scores, and more prolonged postoperative analgesia, but carries increased risk of maternal hypotension requiring vasopressor intervention. Epidural anesthesia provides superior hemodynamic stability and flexibility in anesthetic titration and postoperative analgesia extension, but requires longer time to achieve surgical anesthesia and may result in greater immediate postoperative pain requiring analgesic intervention. Evidence quality remains moderate to low for most outcomes, reflecting heterogeneity in study designs and outcome definitions.

**8. Recommendations for Future Research:**

**1. Prospective, multicentre, randomised controlled trials** directly comparing spinal versus epidural anesthesia with standardised protocols for anesthetic administration, vasopressor use, and outcome measurement

**2. Harmonised outcome definitions and reporting** using standardised instruments (e.g., GRADE methodology for hypotension grading; validated maternal satisfaction scales; standardised NICU admission criteria)

**3. Long-term follow-up studies** (≥6–12 months) assessing postoperative backache, chronic pain, neurological sequelae, and maternal quality of life

**4. Mechanistic investigations** using continuous maternal hemodynamic monitoring, fetal heart rate telemetry, and cerebral oxygenation monitoring to elucidate the paradoxical superior Apgar scores despite higher spinal hypotension

**5. Subgroup analyses** examining treatment effects stratified by spinal dose, caesarean indication, maternal BMI, age, and comorbidities

**6. Cost-effectiveness analyses** comparing direct and indirect costs (anesthetic consumables, vasopressor use, postoperative analgesic consumption) across techniques

**7. Breastfeeding outcomes and early neonatal feeding success** as primary outcomes

**Clinical Practice Implications:**

Anaesthetists should individualise the choice between spinal and epidural anesthesia based on patient factors, clinical context, and institutional resources, rather than adopting a dogmatic approach favouring one technique universally. Both techniques merit continued use in obstetric anesthesia practice, with clinicians developing proficiency in both modalities and capability to rapidly convert between techniques if the chosen approach proves inadequate. Institutional protocols for hypotension management (fluid administration, vasopressor selection, dosing regimens) should be standardised and regularly reviewed to optimise maternal and neonatal outcomes with either anesthetic modality.

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