Research Article

A Comparative Study on The Efficacy of Low Dose 0.5% Bupivacaine and Fentanyl Versus Conventional Dose of Hyperbaric Bupivacaine Alone For Lower Segment Caesarean Section

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Abstract

Background

Spinal anaesthesia is the preferred anaesthetic technique for Lower Segment Cesarean Section (LSCS). Conventional doses of hyperbaric bupivacaine provide effective surgical blocks but are frequently associated with a high incidence of maternal hypotension. This study evaluated whether a low-dose hyperbaric bupivacaine regimen combined with intrathecal fentanyl improves maternal hemodynamic stability while maintaining high-quality operative block characteristics and neonatal safety.

Methods

This prospective, randomized, double-blind clinical trial evaluated 60 American Society of Anesthesiologists (ASA) physical status II parturients undergoing elective LSCS. Participants were randomly allocated into two equal groups (n=30 each):

- Group B (Conventional-dose): Received 0.5% hyperbaric bupivacaine 1.8 mL (9.0 mg).
- Group BF (Low-dose adjuvant): Received 0.5% hyperbaric bupivacaine 1.6 mL (8.0 mg) combined with fentanyl 0.2 mL (10 mcg) intrathecally.

The primary outcomes included sensory and motor block characteristics and postoperative analgesia duration. Secondary outcomes evaluated intraoperative hemodynamic stability, maternal adverse event profiles, and neonatal Apgar scores.

Results

Parturients in Group BF achieved significantly faster sensory onset times to both the T10 and T6 dermatomes compared to Group B ($p = 0.002$ and $p = 0.033$, respectively). The overall duration of effective sensory blockade (96.00 ±10.59 min vs. 82.53 ±15.40 min; $p < 0.001$) and total postoperative analgesia duration (239.27 ±40.69 min vs. 171.07 ±30.58 min; $p < 0.001$) were significantly prolonged in the low-dose fentanyl group.

Hemodynamically, Group BF exhibited superior stability, demonstrating a significantly lower incidence of maternal hypotension (20.0% vs. 46.7%; $p = 0.028$) and a reduced requirement for therapeutic vasopressor support (16.7% vs. 40.0%; $p = 0.045$) with lower total ephedrine consumption (0.82 ±2.21 mg vs. 5.36 ±8.07 mg; $p = 0.004$). Pruritus occurred exclusively in Group BF (20.0% vs. 0.0%; $p = 0.024$). Neonatal Apgar scores at 1 and 5 minutes were statistically comparable between the groups ($p > 0.05$).

Conclusion

A low-dose intrathecal bupivacaine regimen (8.0 mg) co-administered with 10 mcg of fentanyl provides reliable, rapid surgical anesthesia for Cesarean section while significantly mitigating maternal hypotension and vasopressor requirements, with the added benefit of extended early postoperative analgesia.

Keywords: Spinal anesthesia; Hyperbaric bupivacaine; Intrathecal fentanyl; Cesarean section; Maternal hypotension; Obstetric analgesia.

1. Introduction

Lower segment cesarean section (LSCS) is one of the most frequently performed surgical procedures worldwide, and the choice of anesthetic technique plays a pivotal role in ensuring maternal safety, neonatal well-being, and optimal surgical conditions. Over the past few decades, regional anesthesia—particularly spinal anesthesia (SA)—has emerged as the preferred anesthetic modality for cesarean delivery. Spinal anesthesia involves the administration of a local anesthetic agent into the subarachnoid space, producing sensory, motor, and sympathetic blockade of the lower abdomen and lower limbs. The simplicity of the technique, rapid onset of action, minimal drug requirement, and reliable anesthetic effect have contributed significantly to its widespread acceptance in

obstetric practice.

Compared with general anesthesia, spinal anesthesia offers several advantages in cesarean sections, including better maternal awareness, avoidance of airway manipulation, reduced risk of aspiration, and minimal transplacental drug transfer to the fetus. The technique provides excellent muscle relaxation, ensures rapid surgical readiness, and is associated with reduced maternal mortality and morbidity. Furthermore, spinal anesthesia is cost-effective and is associated with a lower incidence of neonatal depression and fewer systemic side effects, making it particularly suitable for obstetric patients. These benefits have established spinal anesthesia as the gold standard anesthetic technique for both elective and emergency cesarean sections.

Several local anesthetic agents have been used for spinal anesthesia, including lidocaine, tetracaine, ropivacaine, and bupivacaine. Among these, bupivacaine—an amide-type local anesthetic—has become the most commonly used agent for spinal anesthesia in cesarean sections due to its long duration of action and favorable sensory-motor block profile. Bupivacaine is commercially available in both isobaric and hyperbaric forms, with hyperbaric bupivacaine being preferred for obstetric anesthesia because of its predictable spread and faster onset. Studies have shown that hyperbaric bupivacaine produces a more rapid onset of sensory blockade at the T4 dermatome level compared with isobaric bupivacaine, which is essential for achieving adequate anesthesia for cesarean delivery.

Despite its widespread use and advantages, spinal anesthesia is not devoid of limitations. One of the most common and clinically significant complications is post-spinal hypotension, which occurs due to sympathetic blockade resulting in vasodilation and decreased venous return. Maternal hypotension can lead to symptoms such as nausea, vomiting, dizziness, and, if severe, compromised uteroplacental perfusion, potentially affecting fetal oxygenation. Another drawback of spinal anesthesia is the relatively limited duration of postoperative analgesia when local anesthetics are used alone, often necessitating early administration of rescue analgesics.

To overcome these limitations, various adjuvants have been added to intrathecal local anesthetics to enhance the quality and duration of anesthesia and analgesia while minimizing adverse effects. Among these, neuraxial opioids such as fentanyl and morphine have been extensively studied and widely used. Fentanyl, a synthetic opioid belonging to the phenylpiperidine group, acts as a potent opioid receptor agonist with rapid onset and relatively short duration of action. These pharmacological properties make fentanyl a preferred intrathecal adjuvant in obstetric anesthesia.

Intrathecal fentanyl has been shown to enhance the analgesic efficacy of local anesthetics without significantly increasing the degree of motor blockade. It provides superior intraoperative analgesia, reduces visceral pain during uterine manipulation, and prolongs the time to first postoperative analgesic request. Additionally, fentanyl has a lower incidence of delayed respiratory depression compared with hydrophilic opioids such as morphine, making it safer for use in parturients. Doses ranging from 10 to 25 mcg of intrathecal fentanyl have been commonly employed as an additive to local anesthetics in spinal anesthesia for cesarean sections.

The addition of fentanyl to intrathecal bupivacaine has demonstrated several clinical advantages. These include reduced requirement for intraoperative supplemental analgesia, lower incidence of nausea and vomiting, improved patient comfort, and prolonged postoperative analgesia. Furthermore, the synergistic effect of fentanyl allows the use of a reduced dose of bupivacaine while maintaining adequate sensory blockade. This dose reduction has been associated with improved hemodynamic stability and a decreased incidence of post-spinal hypotension.

Clinical trials have evaluated the efficacy of fentanyl as an adjuvant to bupivacaine in spinal anesthesia for cesarean section and have reported favorable outcomes in terms of block quality and patient satisfaction. Recent studies suggest that the use of low-dose bupivacaine in combination with fentanyl can provide sufficient anesthesia while minimizing adverse hemodynamic effects. However, despite these promising findings, there remains no clear consensus regarding the optimal minimum dose of bupivacaine that can be safely and effectively used with fentanyl to achieve adequate anesthesia without compromising maternal or fetal safety.

The lack of standardized dosing protocols has led to variability in clinical practice, with anesthesiologists often relying on institutional preferences or personal experience. Determining an optimal low dose of bupivacaine combined with fentanyl could potentially reduce the incidence of hypotension, improve postoperative analgesia, and enhance overall maternal satisfaction, while maintaining adequate surgical anesthesia. This highlights the need for further well-designed clinical studies comparing low-dose bupivacaine combined with fentanyl against conventional doses of hyperbaric bupivacaine alone. In this context, the present study aims to evaluate and compare the anesthetic efficacy, hemodynamic stability, and analgesic profile of these two anesthetic regimens. By

assessing sensory and motor block characteristics, incidence of hypotension, and postoperative analgesia, this study seeks to contribute valuable evidence toward establishing an optimal spinal anesthesia regimen for cesarean section, thereby improving maternal and neonatal outcomes.

2. Methodology

2.1 Study Design & Population

This prospective, randomized, double-blind clinical study evaluated 60 ASA physical status II parturients undergoing elective LSCS at a tertiary care teaching hospital. Ethical clearance was obtained from the Institutional Ethics Committee, and written informed consent was collected from all participants.

2.2 Randomization & Blinding

Participants were randomly assigned to one of two parallel groups (n = 30 each) using a computer-generated random number sequence:

- Group B: Received 0.5% hyperbaric bupivacaine 1.8 mL (9.0 mg).
- Group BF: Received 0.5% hyperbaric bupivacaine 1.6 mL (8.0 mg) + fentanyl 0.2 mL (10 mcg). Identical syringes were prepared by an independent anesthesia technician to maintain strict double-blinding. Both the performing anesthesiologist and the investigator recording perioperative parameters remained blinded to group allocations.

2.3 Anesthetic Technique

All patients were pre-medicated and pre-loaded with Ringer's lactate solution (10-15 mL/kg). In the sitting or lateral position, lumbar puncture was performed at the L3-L4 or L4-L5 interspace using a standard Quincke spinal needle. Following confirmed free flow of cerebrospinal fluid (CSF), the study drug was injected over 15 seconds. Patients were immediately positioned supine with left uterine displacement to prevent aortocaval compression.

2.4 Outcome Measurements

Sensory block was assessed via pinprick every 2 minutes. Onset was defined as the time to reach the T10 and T6 dermatomes, and total sensory duration was recorded as the time to two-segment regression. Motor block was evaluated via the Modified Bromage Scale (0 = no block, 3 = complete block) until full motor function returned. Systolic blood pressure (SBP), diastolic blood pressure (DBP), mean arterial pressure (MAP), and heart rate (HR) were systematically recorded at baseline, 5, 10, 15, 20, 30, 45, 60, 80, and 100 minutes intraoperatively. Hypotension was defined as SBP < 90 mmHg or a > 20% decrease from baseline, managed with therapeutic intravenous ephedrine boluses. Neonatal well-being was documented using Apgar scores at 1 and 5 minutes.

2.5 Statistical Analysis

Continuous variables are expressed as Mean ± Standard Deviation (SD) and compared using the independent-samples student's t-test. Categorical and nominal variables are expressed as frequencies (percentages) and evaluated using the Chi-Square test or Fisher's Exact test as appropriate. Statistical significance was set at $p < 0.05$.

3. Results

3.1 Table 1. Maternal Demographic Data

Variable	Group B (n=30)	Group BF (n=30)	P value
Age (years)	27.67 ±3.51	27.57 ±2.92	0.905
BMI (kg/m2)	27.07 ±3.26	25.94 ±3.22	0.183
ASA Status (II), n (%)	30 (100.0%)	30 (100.0%)	1.000

3.2 Table 2. Anesthetic Block and Analgesia Characteristics

Outcome Parameter	Group B (n=30)	Group BF (n=30)	P value
Time to T10 Sensory Onset (min)	3.90 ±1.13	3.10 ±0.81	0.002
Time to T6 Sensory Onset (min)	6.93 ±1.91	5.91 ±1.72	0.033

Maximum Sensory Height Achieved, n (%)			
* T4	11 (36.7%)	11 (36.7%)	1.000
* T6	16 (53.3%)	16 (53.3%)	
* T8	3 (10.0%)	3 (10.0%)	
Motor Block Onset (min)	4.84 ±1.37	3.96 ±0.89	0.004
Sensory Block Duration / Two-Segment Regression (min)	82.53 ±15.40	96.00 ±10.59	< 0.001
Total Motor Block Duration (min)	122.90 ±26.07	130.20 ±27.40	0.295
Postoperative Analgesia Duration (min)	171.07 ±30.58	239.27 ±40.69	< 0.001

3.3 Table 3. Hemodynamic Outcomes and Interventions

Variable	Group B (n=30)	Group BF (n=30)	P value
Lowest Intraoperative SBP (mmHg)	104.17 ± 10.69	112.93 ± 7.13	< 0.001
Lowest Intraoperative DBP (mmHg)	69.27 ±10.14	70.53 ± 9.13	0.265
Lowest Intraoperative MAP (mmHg)	80.93 ± 8.94	84.63 ± 6.73	0.021
Maximum Heart Rate Deviation (bpm)	82.10 ± 10.75	83.07 ± 10.53	0.726
Incidence of Maternal Hypotension, n (%)	14 (46.7%)	6 (20.0%)	0.028
Vasopressor Requirement (Yes), n (%)	12 (40.0%)	5 (16.7%)	0.045
Total Therapeutic Ephedrine Dose (mg)	5.357 ± 8.065	0.820 ± 2.208	0.004

3.4 Table 4. Complications and Adverse Event Profiles

Variable Outcome	Group B (n=30)	Group BF (n=30)	P value
Maternal Adverse Events, n (%)			
* Bradycardia	5 (16.7%)	2 (6.7%)	0.424
* Nausea	7 (23.3%)	3 (10.0%)	0.299
* Vomiting	4 (13.3%)	1 (3.3%)	0.353
* Pruritus	0 (0.0%)	6 (20.0%)	0.024
* Shivering	7 (23.3%)	4 (13.3%)	0.506
Neonatal Apgar Scores (Mean +/- SD)			
* Apgar at 1 min	7.90 ± 0.71	8.07 ± 0.58	0.325
* Apgar at 5 min	9.03 ± 0.41	9.10 ± 0.48	0.567

4. Discussion

The primary finding of this prospective, randomized, double-blind controlled trial is that decreasing the dose of intrathecal hyperbaric bupivacaine from 9.0 mg to 8.0 mg and co-administering 10 mcg of fentanyl significantly mitigates post-spinal maternal hypotension and subsequent vasopressor reliance during elective Cesarean delivery. Crucially, this local anesthetic dose reduction did not compromise the quality or speed of surgical block onset. Instead, it successfully prolonged the duration of effective early postoperative analgesia without impacting neonatal safety parameters, validating a clinical balance frequently sought in contemporary obstetric anesthesia.

The rapid sensory onset to the T10 and T6 levels observed in Group BF underscores the profound pharmacological synergism between local anesthetics and lipophilic opioid adjuvants in the subarachnoid space. Intrathecal fentanyl concentrates rapidly within the spinal cord dorsal horn, hyperpolarizing nociceptive neurons and suppressing afferent C and A-delta pain signals. This mechanism enhances the density and speed of the sensory blockade, compensating for a reduced mass of bupivacaine. This finding directly corresponds with the definitive trial by Ben-David et al. [43] and observations by Uppal et al., who demonstrated that low local anesthetic volumes supplemented with lipophilic opioids consistently achieve rapid, dense surgical block profiles.

Furthermore, our data confirms that limiting the hyperbaric bupivacaine mass to 8.0 mg curtails extensive cephalad sympathetic inhibition, which is the primary cause of sudden system-wide vasodilation and decreased

venous return in the supine parturient. This physiological preservation is reflected in the significantly higher blood pressure nadirs (SBP and MAP) observed in Group BF, resulting in a dramatic reduction in maternal hypotension from 46.7% to 20.0%. This protective hemodynamic benefit aligns closely with the landmark low-dose strategies popularized by Roofthooft and Van de Velde [40] and the large-scale systematic meta-analysis by Arzola and Wieczorek, which confirmed that minimizing bupivacaine dose fields reduces maternal circulatory collapse while ensuring surgical success.

Environmental stability and protection directly triggered a six-fold reduction in total vasopressor consumption within the adjuvant group (0.82 mg vs. 5.36 mg). In conventional practice, high-dose bupivacaine mandates aggressive, reactive titration of vasopressors like ephedrine to preserve maternal uterine blood flow. By minimizing this dependency, Group BF provides a safer profile for fluid-sensitive obstetric populations. This clinical advantage is strongly supported by Venkata et al., who similarly noted a drastic reduction in reactive vasopressor intervention when utilizing an identical low-dose bupivacaine-fentanyl mixture.

While the sensory block duration and time to first postoperative rescue analgesia request were significantly extended in Group BF, the overall duration of motor blockade remained statistically comparable to the conventional arm ($p = 0.295$). This is an ideal clinical endpoint. It facilitates early maternal mobilization and improves the overall recovery experience, mirroring findings by Sun et al. [44] and Baheti et al..

The primary clinical limitation linked to intrathecal fentanyl adjuvant use was a 20.0% incidence of mild, self-limiting maternal pruritus. This is a well-documented side effect triggered by the cephalad migration of opioid molecules interacting with mu receptors in the medullary dorsal horn, rather than systemic histamine release. This incidence aligns with rates reported across obstetric literature, and no cases in our cohort required pharmacological reversal or disrupted the surgical flow. Finally, neonatal safety remained uncompromised. Excellent, statistically equivalent 1-minute and 5-minute Apgar scores confirmed that a 10 mcg intrathecal dose does not achieve cross-placental concentrations capable of inducing neonatal respiratory or neurobehavioral depression, matching standard safety data established by Liu et al. [57] and Sun et al.

5. Conclusions

Co-administering 10 mcg of intrathecal fentanyl adjuvant with a reduced dose of hyperbaric bupivacaine (8.0 mg) provides safe spinal anesthesia for Cesarean delivery. It provides rapid block onset, superior maternal hemodynamic stability with lower vasopressor requirements, and significantly prolonged early postoperative pain relief without compromising neonatal outcomes.

6. References

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