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Research Article

Efficacy of Low-Dose Hypobaric Anesthetics in Spinal Anesthesia for Cesarean Delivery and Comparison with other Bupivacaine Formulations

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ABSTRACT

Background: Spinal anesthesia remains the technique of choice for elective cesarean delivery. However, conventional doses of intrathecal local anesthetics (e.g., 10 mg-12 mg of hyperbaric bupivacaine 0.5 %) are associated with a high incidence of maternal hypotension, nausea, vomiting, bradycardia, and consequent fetal perfusion concerns. Use of low-dose intrathecal local anesthetics (often <10 mg) either in hypobaric or marginally hyperbaric solutions has been proposed to mitigate these side effects while maintaining adequate surgical anesthesia.

Objective: To review and compare the efficacy and safety of low-dose hypobaric (or marginally hyperbaric) intrathecal anesthetic techniques in cesarean delivery, with particular focus on bupivacaine formulations and resultant maternal/fetal outcomes.

Methods: A narrative review of Randomized Controlled Trials (RCTs), observational studies and recent systematic reviews/meta-analyses was conducted. Outcomes of interest included block adequacy, need for supplementation, hypotension incidence, vasopressor use, recovery times, maternal satisfaction, and neonatal outcomes. Comparisons across different bupivacaine doses, baricities, and adjuvant use (e.g., intrathecal opioids) were made.

Results: Recent meta-analysis (17 trials, 1280 parturients) demonstrated that low-dose hypobaric local anesthetics (<10 mg bupivacaine/levobupivacaine; <15 mg ropivacaine) were associated with a significantly reduced risk of hypotension (RR~0.56, 95% CI 0.43-0.73) but a higher risk of requiring intraoperative analgesic supplementation (RR~3.13, 95% CI 2.14-5.59). Several RCTs confirm that doses as low as 7 mg hyperbaric bupivacaine (with intrathecal opioid) provide adequate surgical anesthesia while improving hemodynamic stability though may require epidural supplementation. PubMed+1 Comparisons of different baricity (marginally hyperbaric *vs* standard hyperbaric) also show lower cephalad spread and less hypotension with preserved efficacy.

Conclusion: Low-dose intrathecal bupivacaine (or other local anesthetics) in hypobaric or marginally hyperbaric form for cesarean delivery can reduce maternal hemodynamic side-effects without meaningful compromise in surgical anesthesia provided appropriate adjuvants (intrathecal opioids) and readiness for supplementation. However, practitioner caution is required given the increased risk of block supplementation or failure, and the need for tailored dosing and monitoring.

Keywords: Cesarean section; Spinal anesthesia; Low-dose bupivacaine; Hypobaric; Hyperbaric; Hypotension; Intrathecal opioid.

INTRODUCTION

Spinal anesthesia is widely used for cesarean delivery because of its rapid onset, dense neural block, and avoidance of airway and general anesthesia related complications. However, the obstetric physiological changes (e.g., decreased functional residual capacity, increased aortocaval compression, heightened sympathetic tone) predispose parturients to major hemodynamic shifts following neuraxial blockade. High levels of sympathetic block may lead to profound hypotension, impaired uteroplacental perfusion, nausea, vomiting and potential fetal acidosis. Traditional intrathecal doses for cesarean section commonly include 10

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mg-12.5 mg of 0.5% hyperbaric bupivacaine (≈ 2.0 mL-2.5 mL) with or without intrathecal opioids. The high incidence of hypotension (in some series up to ~70 %) prompted investigation into dose reduction strategies. Lower intrathecal doses of local anesthetic (e.g., 7-9 mg) or use of hypobaric or marginally hyperbaric solutions may theoretically reduce cephalad spread, limit sympathetic block, and thus improve hemodynamic stability. As such, evaluating the efficacy (in terms of block quality and maternal/neonatal outcomes) of low-dose hypobaric formulations, especially comparing to standard bupivacaine formulations, is of clinical interest.

The aim of this review is to examine available evidence on low-dose hypobaric (or marginally hyperbaric) intrathecal local anesthetics in cesarean delivery, with focus on bupivacaine formulations, and compare outcomes with conventional dose protocols.

MATERIAL AND METHODS

We conducted a comprehensive review of the literature using PubMed, Embase, Web of Science, Cochrane Central, and other databases. Randomized Controlled Trials (RCTs), observational comparative studies, and systematic reviews/meta-analyses were included with no language restriction [1]. Data on intrathecal dose, baricity, use of intrathecal opioid adjuvants, maternal hemodynamics (hypotension incidence, vasopressor use), block adequacy (sensory/motor block, supplementation needed), recovery times, maternal satisfaction, and neonatal outcomes (Apgar scores, acid-base) were extracted and synthesized. A recent meta-analysis was used as a key reference.

RESULTS

Evidence on low-dose intrathecal bupivacaine in cesarean delivery

Several studies have explored reduced intrathecal bupivacaine doses in cesarean delivery:

- A meta-analysis (15 RCTs, 1004 patients; of which 693 patients in 12 RCTs formed the meta-analysis) found that compared with conventional dose bupivacaine, low-dose bupivacaine was associated with a higher risk of analgesic supplementation (RR 3.76, 95% CI 2.38-5.92) but a lower risk of hypotension (RR 0.78, 95% CI 0.65-0.93).
- In the randomized controlled trial by Cenkowski, et al., comparing 4.5 mg *vs* 9 mg intrathecal bupivacaine for elective cesarean section [2], the low-dose group had faster motor recovery times and shorter recovery room stays, but no significant difference in maternal Cardiac Index (CI).
- The RCT by Harten, et al., compared intrathecal hyperbaric bupivacaine 7 mg, 8 mg, or 9 mg (all with intrathecal morphine) in combined spinal-epidural anesthesia for cesarean delivery: Adequacy was maintained in all groups, but hypotension incidence increased with dose: 30% (7 mg) *vs* 55% (8 mg) *vs* 70% (9 mg) [3].
- An observational study comparing 10 mg *vs* 12 mg 0.5% hyperbaric bupivacaine found less blood pressure decline in the lower dose group, though maternal satisfaction was higher in the 12 mg group [4].
- A recent study using low-dose 8 mg 0.5% hyperbaric bupivacaine +25 μg fentanyl *vs* conventional 12 mg found significantly lower hypotension (24.3% *vs* 62.2%) and lower nausea/vomiting in the low-dose group.
- An observational comparative study comparing 2.5 mL *vs* 3 mL 0.5% hyperbaric bupivacaine found equivalent block quality but faster recovery in the low-dose group [5].

Hypobaric/marginally hyperbaric formulations

The baricity of the intrathecal solution influences the spread of anesthesia. A randomized trial compared low-dose (7.2 mg bupivacaine +2 μg sufentanil) in solution of varying glucose/baricity (8% *vs* 0.8% *vs* 0.5% *vs* 0.33% glucose) in elective cesarean sections. The maximum cephalad sensory block height and incidence of hypotension decreased as baricity/density of the solution decreased; yet the quality of anesthesia (sensory/motor) remained similar across groups.

These data suggest that using marginally hyperbaric or hypobaric intrathecal solutions with low doses of bupivacaine may reduce block height and thus reduce sympathetic blockade and hypotension, without compromising surgical blockade.

Comparative summary: Efficacy *vs* safety

From the above data, the following general conclusions can be drawn:

Block adequacy: Low-dose intrathecal bupivacaine (e.g., 7 mg -9 mg) with intrathecal opioid adjuvant appears to provide adequate surgical anesthesia for most elective cesarean deliveries. However, the need for intraoperative supplementation is higher (meta-analysis RR~3).

Hemodynamic stability: Low doses are consistently associated with lower incidence of hypotension, less nausea/vomiting, reduced vasopressor requirement. For example, the meta-analysis reported RR~0.56 for hypotension.

Recovery times: Some RCTs show faster motor recovery and shorter recovery room stay with lower doses (e.g., Cenkowski, et al.,) [2].

Neonatal outcomes: In the studies reviewed, neonatal parameters (e.g., Apgar scores, cord pH) were not significantly different between low and conventional dose groups.

Baricity effect: Lower-density or hypobaric intrathecal solutions reduce block height and hypotension while maintaining adequacy (see marginally hyperbaric trial).

Trade-offs: The principal trade-off appears to be an increased likelihood of needing intraoperative supplementation or perhaps shorter duration of block; thus, the margin for error is smaller with low-dose regimes.

DISCUSSION

The use of low-dose intrathecal local anesthetics for cesarean delivery represents a meaningful advance in obstetric anesthesia-balancing block efficacy and maternal safety. This technique appears especially beneficial in settings where maternal hemodynamic instability would pose higher risk (e.g., pre-eclampsia, cardiac disease, limited vasopressor support). The reduction in hypotension and therefore potential for improved uteroplacental perfusion-may carry neonatal benefit, although large studies powered to detect neonatal acid- base differences are lacking. However, there are important considerations:

Patient and surgical factors

The adequacy of a low-dose block depends on surgical speed, maternal anatomy, adjuvant use (intrathecal opioids), and the ability to convert to supplementation (epidural/spinal top-up) if needed. Surgeons with slower closure times may require longer

block duration than lower-dose anesthetic alone can provide, unless fallback (epidural catheter) is planned.

Adjuvant opioids

Many of the low-dose studies incorporated intrathecal opioids (e.g., morphine, fentanyl, sufentanil) which likely enhance block quality and compensate for reduced local anesthetic dose. For instance, the study with 7-9 mg bupivacaine used 100 μg intrathecal morphine.

Without opioid adjuvant, low-dose may result in inadequate anesthesia. The meta-analysis subgroup analysis showed that when opioid adjuvants were equal between groups, anesthesia effect differences disappeared (RR~1.32, 95%CI 0.58-3.00) [1].

Baricity and spread

Using hypobaric or marginally hyperbaric solutions seems to reduce cephalad spread (hence less high block/hypotension) without sacrificing analgesic efficacy-as long as dose and adjuvants are tailored. This adds another dimension to dose-modulation strategies beyond mere local anesthetic mass.

Block duration and supplementation

Low doses may have shorter duration or narrower margin of safety. The lowest-dose RCT (7 mg) required ability to reinforce *via* epidural if surgery lasted longer. PubMed In settings without epidural fallback, low dose may risk intraoperative "rescue" analgesia or conversion to general anesthesia.

Standardization and heterogeneity

There is considerable heterogeneity in definitions of "low dose," local anesthetic concentrations, baricity (heavy *vs* hypobaric), patient positioning, adjuvant use, and outcome definitions. For instance, the Database of Abstracts of Reviews of Effects (DARE) review notes the arbitrary nature of the "low dose" cut-off in included studies in National Center for Biotechnology Information (NCBI)

Given this, institutional practice adopting low-dose hypobaric intrathecal anesthesia for cesarean section should ensure: (a) operator and obstetric team readiness; (b) plan for supplementation *via* epidural or conversion; (c) use of intrathecal opioid adjuvant; (d) monitoring and vasopressor/intravenous fluid protocols.

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Implications for practice

From a practical perspective in obstetric anesthesia:

- In healthy parturients undergoing elective cesarean section, using 7 mg-9 mg intrathecal bupivacaine (0.5% hyperbaric or marginally hyperbaric) plus intrathecal opioid may be a safe and effective option, with improved hemodynamic profile.
- For institutions or patients at higher risk of hypotension (e.g., hypertensive disorders, volume-unresponsive states), low-dose hypobaric technique may offer safety benefits.
- Surgeons who anticipate longer operative times or in cases where anesthesia duration must be guaranteed, either higher dose or plan for epidural supplementation should be retained.
- Careful institutional protocols (volume preload/coload, left uterine displacement, vasopressor availability) remain essential even in low-dose regimes.
- Further research is needed to define the optimal "minimal effective dose" of intrathecal bupivacaine in diverse populations (e.g., high Body Mass Index (BMI), taller stature, emergent cesarean section) and to evaluate neonatal acid-base/fetal outcomes robustly.

LIMITATIONS

This review is limited by its narrative nature-no new meta-analysis was conducted. Many studies are small, single-centre, and often conducted in elective rather than emergent cesarean deliveries. The heterogeneity of dosages, patient populations, adjuvant use, and surgical durations reduces the generalizability of findings. Moreover, long-term maternal/neonatal outcomes (e.g., neurodevelopment, uteroplacental perfusion) remain under-explored.

CONCLUSION

Low-dose hypobaric (or marginally hyperbaric) intrathecal local anesthetic techniques, especially with bupivacaine, offer an appealing balance between surgical anesthesia efficacy and improved maternal hemodynamic safety in cesarean delivery. When combined with intrathecal opioid adjuvants and with appropriate safeguarding (epidural backup, vasopressor readiness), this approach may reduce hypotension, nausea/vomiting, and recovery times without compromising neonatal outcomes. Institutional adoption of this technique should be accompanied by standardized protocols and adequate monitoring.

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