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Original Research Article

Comparison of Low-Dose versus Standard-Dose Hyperbaric Bupivacaine for Spinal Anesthesia in Elective Lower Limb Surgery: A Prospective Study

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Abstract:

Background: Hyperbaric bupivacaine is effective for most surgical procedures performed in the lower limb, and standard doses have been shown to reliably produce spinal anesthesia, but may also result in hypotension and motor recovery delay after lower limb surgery.

Objective: A comparison of low dose and standard dose 0.5% hyperbaric bupivacaine for elective lower limb surgery with regards to block adequacy, hemodynamics and recovery.

Methods: Ninety ASA I-II older adults for elective surgery on the lower limbs were assigned to 7.5 mg hyperbaric bupivacaine (n=45) and 12.5 mg hyperbaric bupivacaine (n=45). Onset of the sensation, peak, motor recovery, hypotension, vasopressor use, ambulation and satisfaction were documented.

Results: 93.3% in the low dose and 100% in the standard dose group were adequately anaesthetised (p=0.24). Low-dose bupivacaine had slower onset to T12 (5.6 +/- 1.8 versus 4.1 +/- 1.4 minutes, p<0.001) but less hypotension (11.1% versus 31.1%, p=0.021). Complete motor recovery was faster (142.3 +/- 31.2 versus 212.8 +/- 44.5 minutes, p<0.001), and ambulation occurred earlier (238.6 +/- 43.7 versus 335.2 +/- 57.9 minutes, p<0.001).

Conclusion: Low dose hyperbaric bupivacaine proved to be an adequate anesthetic in certain surgeries of the lower limbs and had a more favorable hemodynamic stability and recovery.

Keywords: Spinal Anesthesia, Hyperbaric Bupivacaine, Low Dose, Lower Limb Surgery, Hemodynamic Stability, Motor Recovery.

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Introduction

Spinal anesthesia is one of the most commonly employed techniques for elective surgery on the lower limb, due to its ease, cost-effectiveness and adequate sensory and motor block [1]. The intrathecal use of hyperbaric bupivacaine continues to be a standard local anesthetic because of its predictable spread and duration. Regular doses however, may lead to sympathetic block, hypotension, delay in mobilisation, and urinary retention [2].

A sensible measure for minimizing cephalad spread and reducing the length of the block is to reduce the dose; however, if the dose is reduced too much, the surgical anesthesia may be inferior [3]. Low-dose regimens have been studied in unilateral spinal anesthesia, ambulatory knee arthroscopy and short lower limb procedures, and have been shown to have quicker recovery, and better hemodynamic stability [4,5].

The focus for modern surgery of the lower limb is the early mobilization and the swift discharge from the recovery room and recovery without urinary retention. If the block is dense and lasts after the cessation of the surgical stimulus, then physiotherapy may be delayed and monitoring needs may be raised. Thus, the intrathecal dose should also take into account the anesthetic pathway during surgery and recovery [6].

The spread of hyperbaric bupivacaine is dependent on dose, volume, baricity, speed of injection, patient position, spinal curvature and cerebrospinal fluid volume [7]. A lower dose will have a less profound effect on sympathetic and motor block, but may

result in uneven anesthesia or discomfort with the tourniquet. This balance should be assessed taking into account the anticipated duration of surgery [8].

In many hospitals, no adjustment of the dosage is made for any procedures of the lower limbs, even if the surgery lasts longer. For shorter procedures, this practice is not the most optimal, but it is still reliable. However, a well planned low dose protocol can provide sufficient anaesthetic and improve recovery, reduce hypotension and increase patient throughput.

This is a prospective study that aimed to compare between 7.5 mg and 12.5 mg of 0.5% hyperbaric bupivacaine for elective surgery of lower limbs. The study focused on block adequacy, onset, regression, hemodynamic stability, adverse events, motor recovery and time to ambulation.

Materials and Methods

This is a prospective and comparative study. Patients were adults (18-65 years) with ASA physical status I-II undergoing elective orthopedic surgery or soft tissue surgery of the lower limbs lasting 45-120 minutes. Exclusion criteria included patient refusal, coagulopathy, infection at puncture site, severe hypovolemia, neurological disease, spinal deformity, allergy to amide local anesthetic and anticipated surgery duration > 2 hrs.

Patients were randomly assigned to Group L or Group S by the sealed envelope technique. Group L (1.5 ml) was the group given 0.5% hyperbaric bupivacaine, which equals 7.5 mg. Group S were given 2.5 ml (12.5 mg). In order to evaluate the effect of the dose of bupivacaine, no intrathecal opioid was added.

Spinal anesthesia was performed by 25G Quincke needle in the sitting position following aseptics at level of L3-L4 or L4-L5. Following intrathecal injection, patients were supine and received oxygen by face mask. Hemodynamic variables were measured before and after spinal surgery at regular intervals.

Pinprick was used to evaluate sensory block every 2 minutes for 15 minutes and then at 30-minute intervals. Motor block was measured with the modified Bromage scale. If sensory level was T12 or more with good motor block, surgery was permitted. Supplementation of analgesia or conversion to GA was used to manage inadequate block.

The main outcome was to provide good surgical anesthesia without conversion. Secondary outcomes were onset time, maximum sensory level, duration of sensory block, duration of motor block, hypotension, bradycardia, nausea, urinary retention, time to ambulation and satisfaction. Hypotension was considered as SBP < 90 mmHg or > 20% drop from baseline. Patient identities were preserved by using coded study numbers and a database of the data was prepared which did not include any direct patient identifiers. The care provided during the procedure was consistent with standard care during the peri-ops period and no treatment was withheld that was deemed necessary for patient safety.

The size of the sample was designed to give sufficient power for the primary outcome and to be feasible for a single-center prospective study. All continuous variables were checked for distribution prior to comparison. Results were presented as mean ± SD for normally distributed data, median (IQR) for non-normally distributed data and number (percentage) for categorical data.

All adverse events were operationalized prior to data collection to ensure that all data were collected in the same way. Rescue treatment was per institutional protocols and not by investigator choice. A p-value < 0.05 was taken to be statistically significant and a two-sided analysis was conducted for all analyses.

The use of intrathecal adjuvants was deliberately not used. Analgesia may have been prolonged or differences in the block may have resulted from the use of opioids, clonidine or dexmedetomidine. The study applied the question of practical use in an OR in which adjuvants are not regularly employed, using plain dose comparison.

All patients were monitored for signs and symptoms of high spinal block (dyspnea, upper limb weakness, severe hypotension, nausea and difficulty in speech). Sensory level was retested frequently until it became constant. Before surgery could begin, the block was assessed to see if it was sufficient for the incision and anticipated tourniquet.

The evaluation of ambulatory readiness was done conservatively. Motor power returned and patients noted no dizziness and stable blood pressure, permitting them to stand. This method was chosen because early ambulation is only beneficial when safe, and may actually increase the risk for falling if performed too early after neuraxial anesthesia.

Results

Baseline demographic variables, ASA status, type of surgery and mean surgical duration were comparable between groups. Adequate surgical anesthesia was achieved in 93.3% of low-dose patients and 100% of standard-dose patients. Three low-dose patients required supplemental intravenous fentanyl, and one required conversion to general anesthesia because of inadequate sensory level.

The low-dose group had a slower onset of sensory block and a lower median maximum sensory level. Standard-dose bupivacaine produced denser and longer block, but recovery was significantly delayed. Complete motor recovery occurred

approximately 70 minutes earlier in the low-dose group, and ambulation was achieved earlier.

The distribution of procedures included ankle fixation, tibial implant removal, foot surgery, knee arthroscopy and minor open orthopedic procedures. Tourniquet discomfort requiring fentanyl occurred in four low-dose patients and one standard-dose patient, but it did not lead to cancellation in most cases.

Hemodynamic stability was better in the low-dose group. Hypotension occurred in 5 patients in Group L and 14 patients in Group S. Vasopressor requirement was significantly lower with low-dose bupivacaine. Bradycardia, nausea and urinary retention were infrequent and did not differ significantly.

No patient developed high spinal anesthesia, respiratory compromise or persistent neurological symptoms. Patient satisfaction scores were comparable, suggesting that faster recovery in the low-dose group did not occur at the expense of perceived comfort in appropriately selected procedures.

The difference in recovery profile was evident in the post-anesthesia area. Patients in the low-dose group regained ankle and knee movement earlier and required shorter observation for residual motor block. Nursing staff reported easier transfer and positioning in low-dose patients after regression of block.

Analgesic requirement during the first postoperative hours was slightly higher in the low-dose group, but most patients were managed with routine systemic analgesics. The standard-dose group had longer pain-free duration but also delayed motor recovery. This trade-off should be considered when choosing dose for short versus longer operations.

Patient satisfaction was high in both groups. Patients in the standard-dose group appreciated dense intraoperative anesthesia, whereas patients in the low-dose group appreciated earlier return of movement. No patient reported persistent numbness or neurological symptoms at 24-hour assessment.

Table 1: Demographic and operative profile

Variable	Low dose (n=45)	Standard dose (n=45)	p-value
Age (years)	42.7 +/- 13.2	44.1 +/- 12.5	0.61
Male/Female	27/18	29/16	0.66
BMI (kg/m2)	24.6 +/- 3.6	25.0 +/- 3.4	0.59
ASA I/II	28/17	26/19	0.67
Surgical duration (min)	76.8 +/- 21.5	79.4 +/- 23.1	0.58

Table 2: Block characteristics

Variable	Low dose	Standard dose	p-value
Adequate anesthesia	42 (93.3%)	45 (100%)	0.24
Onset to T12 (min)	5.6 +/- 1.8	4.1 +/- 1.4	<0.001
Maximum sensory level	T10 (T8-T12)	T8 (T6-T10)	0.003
Two-segment regression (min)	84.6 +/- 23.8	126.4 +/- 31.5	<0.001
Complete motor recovery (min)	142.3 +/- 31.2	212.8 +/- 44.5	<0.001

Table 3: Hemodynamic and recovery outcomes

Outcome	Low dose	Standard dose	p-value
Hypotension	5 (11.1%)	14 (31.1%)	0.021
Bradycardia	2 (4.4%)	5 (11.1%)	0.43
Mephentermine required	4 (8.9%)	13 (28.9%)	0.016
Time to ambulation (min)	238.6 +/- 43.7	335.2 +/- 57.9	<0.001
Urinary retention	1 (2.2%)	4 (8.9%)	0.36
Patient satisfaction score	8.6 +/- 1.1	8.8 +/- 1.0	0.37

Discussion

This study revealed that 7.5 mg hyperbaric bupivacaine provided satisfactory spinal anesthesia for most selected lower limb surgeries and fewer occurrences of hypotension as compared to 12.5 mg, and had a significantly quicker motor recovery. These results confirm that intrathecal dose can be adjusted based on the anticipated length of surgery and desired postoperative outcome [9].

An adequacy rate of 93.3% means that dose reduction is possible, but cannot be used interchangeably with standard doses in all cases. The clinician should take into account the level of incision, whether a tourniquet will be used, how long it will be needed for and the patient's anxiety and the implications of general anesthesia. Surgery longer than standard or that isn't predictable should be done at standard dose [10].

It is a great benefit because of the decrease in hypotension. A decrease in blood pressure after spinal anesthesia is caused by sympathetic block and venous pooling. In the present study, patients were predominantly ASA I-II, but the benefit could be clinically important in patients in which maintaining blood pressure is important [11].

Improved Motor Recovery can enhance Turnover and Patient Comfort. In ambulatory or short-stay, patients may not be discharged until the motor block is taken off even if the pain is relieved. Encouraging earlier ambulation will help in decreasing the time spent on nursing observation and could help with early physiotherapy following orthopedic surgery [12].

The standard-dose group had a higher sensory spread and a quicker onset, so it is not surprising that the rate of adequacy for this group was complete. But there were also more hypotension and delayed recovery. Therefore, an intrathecal dose should be selected based on clinical considerations, such as reliability and recovery profile.

Careful positioning, unilateral technique, pencil-point needles and adjuvants are several strategies that will improve the reliability of low doses. The use of intrathecal opioids can enhance the analgesic effect and can cause pruritus or urinary retention and/or nausea. In this study, bupivacaine dose was evaluated without any intrathecal adjuvants [13].

The limitations are a moderate number of samples and the lack of long term follow-up and heterogeneous procedures. Height-adjusted dosing, cerebrospinal fluid volume and baricity variations were not assessed. Future research should include ambulatory discharge criteria that have been validated [14,15] and determine the minimum effective doses for each procedure.

The study emphasizes the importance of balancing adequacy and recovery in spinal anesthesia. A higher dose will increase the likelihood of dense surgical anesthesia, or lengthen the duration of sympathetic and motor block. A lower dose is better for recovery, but has a more demanding selection of patients and procedures.

The low dose regimen could be especially helpful for moderate length procedures on the lower limb for which early mobilization is essential. It could also be considered in patients with a higher risk of hypotension, if surgery duration is anticipated and conversion plans are in place.

The results do not warrant the use of low dose spinal anesthesia for all surgeries of the lower extremity. Standard dosing, or adjuvanța may be necessary for procedures requiring long periods of tourniquet inflation, or significant bone manipulation, or duration that is unknown. A one-size-fits-all approach is not a suitable strategy; it is better to individualize.

Further research could look at the effect of dose adjustment according to height, age and CSF volume. Ultrasound-assisted neuraxial landmarking can also enhance the 1st pass spinal success and minimize the variability. This may be another avenue to achieve block quality and recovery using the combination of low dose bupivacaine and short-acting adjuvants.

It is critical to understand that there is a difference between the recovery of sensory and motor function. Even with adequate analgesia, a patient may not be able to move the lower limbs safely. With day care and short-term surgery, motor function is frequently the most important determinant of discharge and is a clinically relevant endpoint.

The lower sensory level was seen in the low dose group, and may have been a contributor to reducing the number of hypotensive episodes. A partial sympathetic block may maintain vascular tone and minimize the necessity of vasopressor therapy. This is important especially if hypotension can affect organ perfusion or delay surgical procedures.

The few inadequate blocks in the low-dose group emphasize the need for rescue planning. The anaesthetist should ensure that if the block is inadequate there is a safe way to provide supplemental analgesia, sedation or general anaesthesia before deciding on a reduced dose.

Patient counselling is also important. Patients should be told that they could move sooner with a lower dose but it might not give them the same numbness for a longer period of time. This helps to set expectations and can alleviate anxiety if there is a greater return of sensation than expected.

The optimum dose for some procedures may be somewhere between the two doses tested in practice. Sequential allocation and minimum effective dose designs can be used to find a better balance of block reliability and rapid recovery in dose-finding studies.

Implementing low-dosed spinal anesthesia necessitates coordination with the surgeon and recovery team. The surgeon should ensure that the expected length of regression and incision is suitable; the recovery team should be aware that regression is not a complication, but an intended outcome. Block level documentation, time to regression and ambulation readiness can further guide optimal dosing. The present results indicate that low-dose hyperbaric bupivacaine may enhance the recovery efficiency in the selected procedure as long as it is accompanied by precise rescue plans and a proper communication during the procedure itself. [11]

There are two points to coordinate with the surgeon and recovery team for clinical implementation of low dose spinal anesthesia: The length of time and the depth of the incision should be confirmed by the surgeon, and the recovery team should be aware that regression is a desired result, not a problem or complication. Data on block level, time to regression and ambulation readiness can provide useful information to guide a more precise choice of doses in the future. Based on the present results, low-dose hyperbaric bupivacaine may facilitate the efficiency of recovery during selected procedures, provided that appropriate rescue plans and informative communication between the surgeon and the anesthesiologist are used.

Conclusion

In selected elective surgeries of the lower limb, low dose 7.5 mg hyperbaric bupivacaine was found to be an adequate spinal anesthesia with significantly lesser hypotensive episodes, lesser vasopressor use and early motor recovery when compared with standard dose 12.5 mg bupivacaine. A standard dose bupivacaine provided a more consistent level of block density, but also caused a delay in recovery.

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