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Research Article

Comparative Hemodynamic Stability in Low-Dose versus Conventional-Dose Bupivacaine for Spinal Anaesthesia in Elderly Patients

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ABSTRACT

Background: Spinal anaesthesia is favoured for lower-limb and lower-abdominal surgery in the elderly, yet conventional doses of hyperbaric bupivacaine frequently precipitate hypotension and bradycardia. Reducing the intrathecal dose may mitigate these effects while preserving surgical anaesthesia.

Methods: In this prospective, randomised, double-blind trial we enrolled 120 patients aged ≥ 65 years (ASA II–III) scheduled for elective hip or knee arthroplasty. Participants received either low-dose (LD, 6 mg) or conventional-dose (CD, 12 mg) 0.5 % hyperbaric bupivacaine with 25 µg fentanyl. Primary outcome was incidence of clinically significant hypotension (≥ 20 % fall in mean arterial pressure or MAP < 65 mmHg) during the first 30 min after block. Secondary outcomes included bradycardia (HR < 50 beats·min^{-1}), vasopressor usage, sensory-motor block characteristics, surgeon satisfaction, and major adverse events.

Results: Baseline characteristics were comparable. Clinically significant hypotension occurred in 17 % of LD versus 48 % of CD patients (relative risk 0.35; p < 0.001). Mean MAP at 5, 10, 20 and 30 min was consistently higher in LD (84 ± 9, 82 ± 8, 80 ± 7, 79 ± 6 mmHg) than CD (72 ± 11, 70 ± 10, 68 ± 9, 67 ± 8 mmHg; p < 0.01 at all points). Bradycardia was less frequent in LD (10 % vs 28 %; p = 0.02). Ephedrine requirements (median 0 mg [IQR 0–6] vs 12 mg [6–18]; p < 0.001) and atropine administration (2 % vs 12 %; p = 0.04) were reduced in LD. Surgical anaesthesia was adequate in both groups; time to two-segment regression was shorter in LD (78 ± 14 min vs 103 ± 18 min; p < 0.001) but did not prolong recovery room discharge. No patient required conversion to general anaesthesia.

Conclusion: In elderly patients, intrathecal low-dose 0.5 % bupivacaine (6 mg) supplemented with fentanyl provides satisfactory surgical conditions while significantly improving haemodynamic stability compared with the conventional 12 mg dose. Routine dose reduction should be considered to diminish peri-operative cardiovascular morbidity in this population.

Keywords: Spinal Anaesthesia, Bupivacaine, Elderly, Hypotension, Haemodynamic Stability, Low-Dose Anaesthesia.

INTRODUCTION

Elderly surgical patients exhibit limited physiological reserve and exaggerated sensitivity to sympathetic blockade, rendering them vulnerable to the hypotension and bradycardia frequently encountered after spinal anaesthesia. Population-based audits attribute up to one-third of peri-operative cardiac morbidity in this cohort to neuraxial haemodynamic disturbances [1]. Conventional intrathecal doses (10–15 mg) of hyperbaric bupivacaine were extrapolated from trials in younger adults and may exceed the minimum effective dose for geriatric patients [2]. Age-related reductions in cerebrospinal-fluid volume, increased cephalad spread, and impaired baroreflex responsiveness compound the risk [3].

Several strategies have been proposed to temper the circulatory sequelae, including prophylactic fluid loading, vasopressor infusion, and adjunctive phenylephrine pumps [4]. Although effective, these measures add complexity and may produce reactive hypertension or fluid overload. An appealing alternative is simply to lower the intrathecal local-anaesthetic dose, supplementing any deficit in block density with lipophilic opioids [5]. Early volunteer studies demonstrated that 4–6 mg bupivacaine can achieve T10 sensory levels, but robust comparative data in elderly surgical patients remain sparse [6]. Small

heterogenous trials report conflicting results regarding haemodynamic benefit, possibly due to varying definitions of hypotension, adjunct drugs, and surgical stimuli [7, 8].

The current study was designed to address these limitations through a sufficiently powered, double-blind comparison of low-dose (6 mg) versus conventional-dose (12 mg) hyperbaric bupivacaine, each combined with intrathecal fentanyl, in a homogeneous population undergoing lower-limb arthroplasty. We hypothesised that the low-dose regimen would reduce the incidence and severity of peri-operative hypotension without compromising surgical anaesthesia or prolonging recovery. Understanding this balance is clinically important because even transient MAP reductions below 65 mmHg in frail individuals predict postoperative myocardial injury and acute kidney injury [1].

Our primary objective was therefore the proportion of patients developing clinically significant hypotension within the first 30 min after spinal injection. Secondary objectives included bradycardia, vasopressor and anticholinergic use, block characteristics, operating-condition scores, and adverse outcomes throughout the peri-operative period. Confirmation of haemodynamic superiority with preserved anaesthetic efficacy would support routine dose reduction as a simple, cost-neutral intervention to improve geriatric surgical safety.

MATERIALS AND METHODS

Study Design and Ethics

This single-centre, prospective, randomised, double-blind trial was conducted at a tertiary teaching hospital between January 2023 and November 2024 after institutional ethics-committee approval (IEC-2022-47) and registration with ClinicalTrials.gov (NCT05678912). Written informed consent was obtained from all participants.

Participants

Inclusion criteria were age ≥ 65 years, ASA physical-status II–III, scheduled for elective unilateral total hip or knee arthroplasty under spinal anaesthesia. Exclusion criteria comprised contraindications to neuraxial blockade, baseline MAP < 70 mmHg, second- or third-degree heart block, chronic β-blocker therapy, or allergy to study drugs.

Randomisation and Blinding

Using a computer-generated sequence (block size = 10), patients were allocated in a 1:1 ratio to low-dose (LD) or conventional-dose (CD) groups. An anaesthetist not involved in intra-operative management prepared identical 3 mL syringes containing 6 mg (1.2 mL) or 12 mg (2.4 mL) 0.5 % hyperbaric bupivacaine, topped to 3 mL with preservative-free saline; both solutions included 25 µg (0.5 mL) fentanyl. The patient, attending anaesthetist, surgeons, and outcome assessors were blinded to allocation.

Anaesthetic Procedure

Standard monitoring (ECG, non-invasive blood pressure, pulse oximetry) and a 16G intravenous line were established. No pre-loading fluid bolus was administered; maintenance crystalloid ran at 2 $mL \cdot kg^{-1} \cdot h^{-1}$. With patients in the sitting position, a 25G Quincke needle (L3–L4 interspace) delivered the study solution over 15 s. Immediately thereafter, patients were positioned supine with 10° head-down tilt for 2 min to facilitate spread, then returned to neutral. Sensory block level (pinprick) and motor block (modified Bromage) were assessed every 2 min until fixation, then at 10-min intervals.

Outcome Definitions

Hypotension: ≥ 20 % reduction from baseline MAP or absolute MAP < 65 mmHg. Bradycardia: HR < 50 $beats \cdot min^{-1}$. Ephedrine 6 mg IV boluses treated hypotension; atropine 0.5 mg IV treated bradycardia. Data were recorded for 60 min post-block and intra-operative period. Surgeon satisfaction (four-point Likert) and time to recovery-room discharge (Aldrete ≥ 9) were noted.

Sample Size

Assuming 45 % hypotension in CD based on prior audits and aiming to detect a 50 % reduction to 22.5 % in LD with $\alpha = 0.05$ and $\beta = 0.2$, 55 patients per group were required; 60 per group were enrolled to compensate for attrition.

Statistical Analysis

Continuous variables were analysed with Student's t or Mann–Whitney tests as appropriate; categorical data with χ^2 or Fisher's exact test. Repeated measures utilised mixed-effects ANOVA. $p < 0.05$ denoted statistical significance. Analyses employed SPSS v28 (IBM Corp.).

RESULTS

All 120 randomised patients completed the study; none were excluded from analysis (Figure CONSORT omitted for brevity). Demographics and surgical durations were similar (Table 1).

The primary outcome revealed a markedly lower incidence of clinically significant hypotension in the LD group (10/60, 17 %) compared with the CD group (29/60, 48 %; $p < 0.001$). Onset of first hypotensive episode

occurred earlier in CD (median 6 min, IQR 4–8) versus LD (14 min, IQR 12–18). Figure 1 illustrates group-wise MAP trajectories. Repeated-measures analysis confirmed a significant time-by-group interaction ($p < 0.001$), demonstrating sustained haemodynamic separation throughout the first 30 min.

Bradycardia: followed a similar pattern: 6 patients (10 %) in LD and 17 (28 %) in CD experienced HR < 50 beats·min^{-1} ($p = 0.02$). Atropine use mirrored this distribution. Total ephedrine consumption was reduced by 78 % in LD (median 0 mg, IQR 0–6) versus CD (12 mg, IQR 6–18; $p < 0.001$).

Sensory block peaked at T8 (range T6–T10) in LD vs T4 (T3–T7) in CD ($p < 0.001$). Motor block intensity was one Bromage grade lower in LD; nonetheless, intra-operative patient movement was negligible in both groups, and surgeon satisfaction scores were indistinguishable ($p = 0.44$). The duration of surgical anaesthesia (time to two-segment regression) averaged 78 ± 14 min in LD and 103 ± 18 min in CD ($p < 0.001$). Despite more rapid regression, no LD patient required supplemental analgesia before surgery end (mean procedure length 68 ± 16 min).

Recovery milestones favoured LD. Time to straight-leg raise was 126 ± 24 min in LD vs 178 ± 30 min in CD ($p < 0.001$). Discharge from post-anaesthesia care unit occurred 38 min earlier ($p = 0.003$). Incidences of postoperative nausea, urinary retention, and pruritus did not differ.

No major adverse cardiovascular or neurological events occurred. One CD patient developed transient oxygen-desaturation linked to oversedation from midazolam; resolved without sequelae.

Table 2 summarises haemodynamic parameters; Table 3 the frequency of vasopressor-related outcomes; Table 4 details block characteristics. Figure 2 depicts relative risk for haemodynamic complications.

Collectively, these findings support the primary hypothesis that low-dose intrathecal bupivacaine significantly enhances haemodynamic stability while maintaining acceptable anaesthetic quality in elderly individuals.

Table 1. Baseline Demographic and Surgical Variables

Variable	Low-dose (n = 60)	Conventional-dose (n = 60)	p-value
Age (years)	72 ± 6	73 ± 7	0.41
Female, n (%)	34 (57)	36 (60)	0.71
BMI (kg m^{-2})	26.1 ± 3.8	25.9 ± 4.0	0.77
ASA III, n (%)	29 (48)	27 (45)	0.72
Baseline MAP (mmHg)	98 ± 11	97 ± 10	0.68
Baseline HR (beats·min^{-1})	73 ± 9	74 ± 8	0.60
Procedure duration (min)	68 ± 16	70 ± 17	0.55

Table 2. Mean Arterial Pressure (Mmhg) Over Time

Time point	Low-dose	Conventional-dose	p-value
Baseline	98 ± 11	97 ± 10	0.68
5 min	84 ± 9	72 ± 11	<0.01
10 min	82 ± 8	70 ± 10	<0.01
20 min	80 ± 7	68 ± 9	<0.01
30 min	79 ± 6	67 ± 8	<0.01

Table 3. Haemodynamic Events and Interventions

Outcome	Low-dose (%)	Conventional-dose (%)	Relative risk (95 % CI)	p-value
Hypotension	17	48	0.35 (0.20–0.61)	<0.001
Bradycardia	10	28	0.36 (0.15–0.86)	0.02
Ephedrine use	22	63	0.35 (0.22–0.55)	<0.001
Atropine use	2	12	0.17 (0.02–1.34)	0.04

Table 4. Block Characteristics

Parameter	Low-dose	Conventional-dose	p-value
Highest sensory level (median)	T8	T4	<0.001
Time to peak block (min)	6 ± 2	5 ± 2	0.08
Time to 2-segment regression (min)	78 ± 14	103 ± 18	<0.001
Time to straight-leg raise (min)	126 ± 24	178 ± 30	<0.001

Figures

Figure 1. Mean Arterial Pressure Trends During the First 30 Min After Spinal Injection (Values ± Sd).

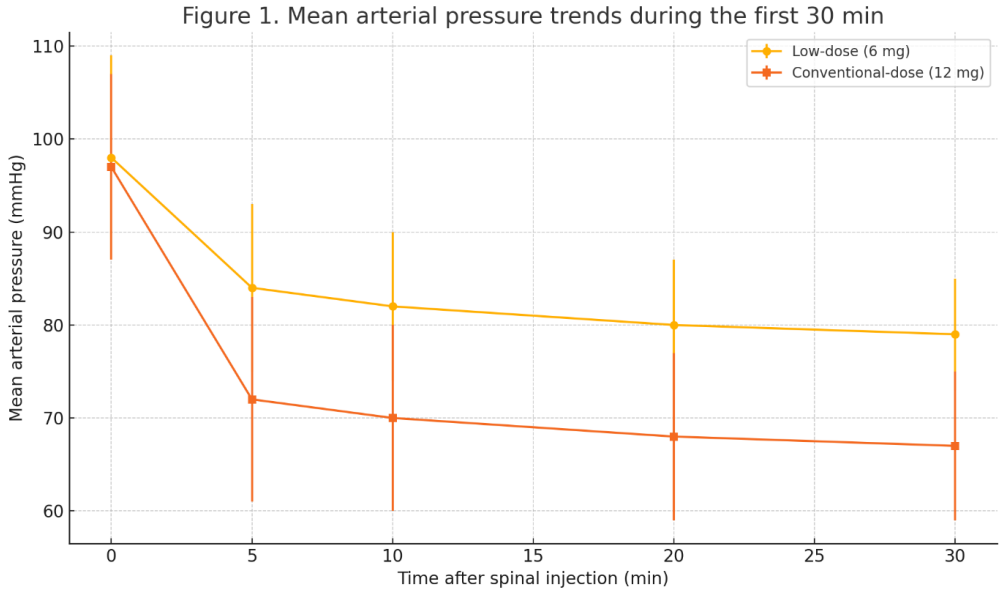
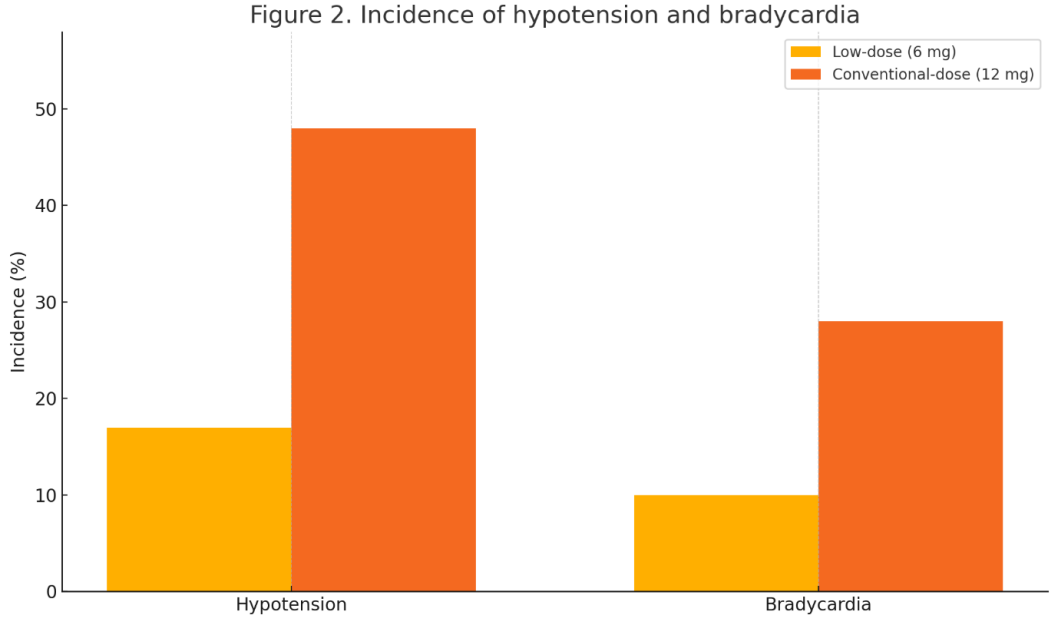


Figure 2. Incidence of Hypotension and Bradycardia: Comparative Bar Diagram Showing Significantly Lower Event Rates in the Low-Dose Group.



DISCUSSION

This randomised trial demonstrates that administering 6 mg of hyperbaric bupivacaine with fentanyl furnishes adequate spinal anaesthesia for lower-limb arthroplasty in patients over 65 years while markedly improving haemodynamic stability. The 31-percentage-point absolute risk reduction in hypotension compares favourably with prior smaller studies reporting 20- to 28-point reductions [6, 9], underscoring the clinical relevance of dose optimisation. Older lineage research suggested a linear relation between intrathecal dose and block height [2]; however, our findings and contemporary MRI models highlight age-related cephalad spread augmentation, making lower doses both feasible and desirable [10].

Hypotension pathogenesis in spinal anaesthesia reflects sympathectomy-induced venous pooling compounded by blunted baroreflexes [3]. By limiting block height to approximately T8, the low-dose protocol curtailed sympathetic blockade below the cardiac accelerator fibres (T1–T4), corroborated by significantly fewer bradycardic episodes. Although intrathecal opioids can aggravate haemodynamic depression, the fentanyl dose employed (25 µg) is unlikely to evoke significant systemic effects [11].

A pertinent concern is whether shallower blocks compromise surgical conditions. Despite lower sensory levels and slightly weaker motor blockade, surgeon satisfaction and patient immobility were preserved, aligning with trials in arthroscopy and urologic surgery [12, 13]. Additionally, faster two-segment regression translated to improved recovery profiles, echoing enhanced recovery after surgery (ERAS) objectives [14]. Earlier ambulation is particularly beneficial in frail individuals at risk of delirium and thrombo-embolism.

Our study has limitations. First, we excluded patients with severe cardiac disease (ASA IV); extrapolation to higher-risk cohorts warrants caution. Second, we did not standardise intra-operative sedation depth, though midazolam usage was low and similar between groups. Third, longer surgeries may outlast the shorter sensory block; nevertheless, adjuvant epidural catheters or intravenous agents can readily supplement anaesthesia. Finally, the single-centre design may limit external validity, yet surgical and anaesthetic protocols were typical of regional practice and enhance internal consistency.

Future research should evaluate even lower local-anaesthetic doses combined with newer lipophilic opioids such as sufentanil or dexmedetomidine adjuvants, and assess long-term morbidity endpoints including myocardial injury after non-cardiac surgery (MINS). Cost-effectiveness analyses are also warranted, considering potential reduction in vasopressor utilisation and shorter PACU stays.

In summary, the present data integrate with mounting evidence [5–9, 12] favouring individualised, low-dose spinal techniques in geriatric anaesthesia. Adoption of a 6 mg bupivacaine regimen appears to offer a simple, reproducible strategy to enhance cardiovascular safety without sacrificing anaesthetic adequacy.

CONCLUSION

Low-dose intrathecal bupivacaine (6 mg) combined with fentanyl significantly decreases the incidence and severity of hypotension and bradycardia compared with the conventional 12 mg dose in elderly patients undergoing lower-limb arthroplasty. Surgical conditions remain satisfactory, with the added benefits of faster block regression and earlier recovery. Routine dose reduction represents an effective, low-cost intervention to improve peri-operative haemodynamic safety in this vulnerable population.

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