Section: Anaesthesia

Original Research Article

A RETROSPECTIVE, OBSERVATIONAL, SINGLE-CENTRE COHORT STUDY ANALYSING THE HEMODYNAMIC EFFECTS OF LOW-DOSE SPINAL ANAESTHESIA IN TOTAL KNEE ARTHROPLASTY SURGERY FOR ELDERLY PATIENTS WITH HIGH CARDIOVASCULAR RISK

Sarita Joglekar[1], Kiran Vyawahare[2]

[1]Consultant Anaesthesiologist, National Cancer Institute, Jamtha, Nagpur, India.
[2]Associate Professor, Department of Anesthesia and Pain Medicine, Shalinitai Meghe hospital and research center, Hingna road, Wanadongri, Nagpur, India.

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Corresponding Author:
Dr. Kiran Vyawahare
Associate Professor, Department of Anesthesia and Pain Medicine, Shalinitai Meghe hospital and research center, Hingna road, Wanadongri , Nagpur, India.
Email: kiranvyaw@yahoo.co.in

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ABSTRACT

Background: Ischemic heart disease is a significant contributor to perioperative morbidity and mortality, posing challenges in the selection and management of anaesthetic techniques. This study aimed to evaluate the efficacy, hemodynamic effects, and postoperative outcomes of unilateral spinal anaesthesia in elderly patients with ischemic heart disease with high cardiovascular risk for anaesthesia undergoing total knee arthroplasty.

Materials and Methods: This retrospective, observational study included 200 high-risk elderly patients with cardiac comorbidities who underwent total knee arthroplasty under unilateral spinal anaesthesia using low-dose hyperbaric bupivacaine. The study was conducted between march 2018 to march 2021.Inclusion criteria comprised patients diagnosed with ischemic heart disease having moderate ejection fraction. Data were collected on patient demographics, cardiac conditions, intraoperative hemodynamics and perioperative complications.

Results: Majority, 168 patients (84%), maintained stable haemodynamics without any vasopressor support. In patients requiring noradrenaline, the infusion was typically initiated early (between 3 to 9 minutes post-SAB) and discontinued within 25 to 60 minutes, indicating that the hypotensive episodes were generally transient and responsive to intervention.

Conclusion: Spinal anaesthesia using a low dose of local anaesthetic is a safe and effective technique for performing total knee arthroplasty in this high-risk cardiac with minimal reductions in blood pressure.

Keywords: Low-Dose Spinal Anaesthesia, Total Knee Arthroplasty, Elderly Patients.

INTRODUCTION

Subarachnoid block is widely regarded as a relatively safe anaesthesia technique due to its minimal impact on myocardial contractility and only a moderate reduction in cardiac output.[1] this makes it particularly beneficial for patients with cardiovascular conditions, especially those diagnosed with ischemic heart disease and congestive heart failure (CHF). In individuals with CHF, sympathetic nervous system activity is typically elevated, which can lead to a more pronounced drop in systemic vascular resistance and blood pressure following spinal anaesthesia, compared to those with normal left ventricular function.[2-4] Research has indicated that administering lower doses of local anaesthetics during spinal blocks can help mitigate the risk of hypotension. For instance, elderly patients undergoing hip surgery who received just 5 mg of

bupivacaine experienced a lower incidence of hypotensive episodes.[5] Further restricting spinal anaesthesia to relevant surgical side i.e unilateral side may further reduce hemodynamic perturbations.

Unilateral spinal anaesthesia is performed by administering a low dose of local anaesthetic at a slow rate while keeping the patient in the lateral decubitus position for about 10 to 15 minutes. This technique allows the anaesthetic to concentrate on one side, providing a selective motor and sensory block limited to the surgical area. As a result, it reduces the likelihood of systemic side effects such as hemodynamic instability and supports quicker recovery of the block. Although several studies have highlighted the benefits of unilateral spinal anaesthesia over general anaesthesia and peripheral nerve blocks in elderly patients, its use in individuals with IHD remains under-investigated. In this retrospective study, we aimed to evaluate the safety and effectiveness of unilateral spinal anaesthesia in elderly patients with IHD with lower ejection fraction undergoing knee replacement surgery. To achieve this, we examined intraoperative anaesthesia-related parameters and short- to mid-term mortality outcomes.

MATERIALS AND METHODS

This was a retrospective observational study conducted on patients who underwent unilateral Total Knee Replacement (TKR) under unilateral spinal anaesthesia at a tertiary care centre. Data was collected from patient medical records from march 2018 to March 2021

Total of 200 patients undergoing unilateral knee arthroplasty having ischemic heat disease and have undergone active coronary intervention (CABG, PTCA) were included. Those with Ejection fraction of less than 30%, ASA grade IV, requiring TKA with other lower limb surgeries and requiring general anaesthesia, those on antithrombotic therapy with impaired coagulation parameters, individuals with infections at the intervention site, those who had undergone previous surgical interventions in the targeted area, individuals with severe spinal deformities, neurological diseases, uncooperative patients, those with peripheral nerve diseases, and patients with known allergies to local anaesthetic drugs were excluded. All data was collected from patient admission sheet collected from medical record department. Patient's demographic characters, medical comorbidities, drug history and preoperative investigations including ejection fraction was recorded preoperatively. Patients vitals Mean Arterial Pressure (MAP), Heart Rate (HR), and SPO_2 recorded at four standardized time points: pre-operation (before spinal anaesthesia), 20 minutes post-spinal injection, intraoperatively (defined as the mean during the surgical procedure), and post-operation (immediately upon transfer to recovery/PACU). Duration of surgery, vasopressor requirement and adverse events if any were recorded.

All participants in the study received similar institutional and anaesthetic care. Throughout their hospital stay, they were managed according to a standardized, multidisciplinary care pathway for knee arthroplasty, overseen by experienced anaesthesiologist.

Unilateral spinal anaesthesia was administered to patients identified as high cardiac risk, provided their coagulation profile was normal and no contraindications to spinal anaesthesia were present. Throughout the study period, all elderly patients who met the inclusion criteria were managed with this anaesthesia approach, except those with the aforementioned contraindications. Blood pressure was monitored at five-minute intervals during both the intraoperative and postoperative phases using an upper arm cuff (NIBP). Continuous IABP was also monitored wherever mandated.

Prior to spinal anaesthesia pts who were anxious were given sedation having an, patients received fentanyl at a dose of 0.5mcg /kg for analgesia and midazolam at 0.02 mcg/kg for sedation. These were administered before patient positioning. Patients were then placed in the lateral decubitus position, with their chin brought toward the chest to the greatest possible extent. Following antiseptic preparation with povidone-iodine, hyperbaric bupivacaine (6.5–7.5 mg) was injected using a 23 or 25-gauge Quincke needle via the median approach at either the L3/L4 or L4/L5 interspace.

The lateral position was maintained until the spinal block was fully established, confirmed using the pinprick method. After confirmation, patients were turned to a supine position for the surgical procedure. All surgeries were performed with patients in the supine position.

The statistical analysis was conducted utilizing the SPSS 24 software (Statistical Package for the Social Sciences Inc., Chicago, IL, USA). The data is expressed as mean ± standard deviation (SD), median (M), and the range between minimum and maximum values. The Mann-Whitney U test was employed for continuous variables, while the Chi-square test was applied for categorical variables. The significance level for all tests was set at $P < 0.05$.

RESULTS

The mean age of the study cohort was 64.07 ± 8.1 years, indicating a predominantly elderly surgical population. Patients had a mean weight of 64.68 ± 4.85 kg and height of 161.54 ± 6.17 cm, corresponding to an approximate mean BMI of 24.8 kg/m^2, suggesting a normal-to-overweight range. The mean Ejection Fraction (EF) was 46.07 ± 4.87%, with a minimum of 35%, confirming the inclusion of patients with moderate cardiac compromise. Preoperative INR values (mean 1.15 ±

0.08) were consistently within the safe surgical range, ensuring no inherent coagulopathy risks. The average surgery duration was 116.36 ± 8.81 minutes.

Of the 200 patients, 104 (52%) were female and 96 (48%) were male, showing a slight female predominance. The majority of patients (190, 94.9%) were classified as ASA Grade II, indicating mild systemic disease, while a small proportion (10, 5.1%) were ASA Grade III. Surgical procedures were almost equally distributed between left (97, 48.5%) and right (103, 51.5%) Total Knee Replacements, with the unilateral spinal anaesthesia block administered on the corresponding side Peripheral capillary oxygen saturation (SPO_2) levels were consistently excellent

In this group, the majority of patients (95%) had EF >39%, indicating that most had preserved or mildly impaired heart function. Ten patients (5%) had EF between 35–39%, which indicates moderately reduced heart function. These 10 patients underwent coronary angiography. 190 patients (95%) had EF greater than 39%. These patients underwent DSE (Dobutamine Stress Echocardiography) instead of coronary angiography. DSE is a non-invasive stress test used to assess heart function and detect ischemia when EF is relatively preserved. [Figure 1]

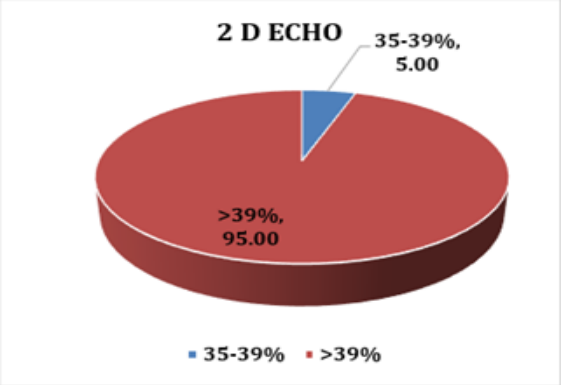

Figure 1: Pie diagram showing ejection fraction in given study population.

Table 1: Demographic and Baseline Clinical Characteristics

Patient characteristics	N(%)	Mean±SD	Median (IQR [range])
Age (years)		64.07± 8.1	42-77(66)
Gender Male Female	96(48%) 104(52%)		
ASA II III	190(95%) 10(5%)		
Weight (kg)		64.68 ±4.85	53-73(66)
Height (cm)		161.54± 6.17	148-178(160)
2D ECHO EF (%)		46.07 ±4.87	35-56(46)
INR		1.15± 0.08	1-1.4(1.12)
Surgery time (min)		116.36± 8.81	90-150(116)
SpO2 (%)		97.93± 0.87	95-100(98)

Table 2: Intraoperative hemodynamic Variables

Variable	Preoperative Mean±SD	Intraoperative Mean±SD	Postoperative Mean±SD	P value
Maen Blood Pressure (mmHg)	95.43±6.92	86.67±6	89.82±4.22	< .00001
Heart Rate (per min)	65.44 ± 6.77	64.29± 6.32	64.11± 5.47	< .02
SpO2(%)				

p Value <0.05 is considered significant.

The Mean Arterial Pressure (MAP) demonstrated a statistically significant change across the measured time points ($F = 72.79$, $p < 0.00001$). A transient decline was observed from a preoperative mean of 95.43 mmHg to 86.67 mmHg during the intraoperative period (representing 20 minutes post-spinal). Subsequently, MAP partially recovered to 89.82 mmHg in the postoperative period. Despite this statistically significant difference, the MAP values remained within a clinically acceptable range, and the recovery postoperatively indicates effective hemodynamic management [Table 2].

Heart rate exhibited remarkable stability throughout the perioperative period. The mean HR changed minimally from 65.44 bpm pre-op to 64.11 bpm post-op. Although the ANOVA result ($F = 3.85$, $p = 0.02$) indicated a statistically significant difference across time points, the absolute change in mean HR was clinically marginal (approximately 1-2 bpm), suggesting overall cardiac stability rather than true variability.

Table 3: Vasopressor Requirement and duration

Variable	N(%)	Minimum time following spinal anaesthesia	Maximum time following spinal anaesthesia
Noradrenaline infusion requirement Yes No	 32(16%) 168(84%)		
Noradrenaline initiation time		3 minutes	9 minutes
Noradrenaline stopping time		25 minutes	60 minutes

Out of 200 patients, 32(16%) required noradrenaline infusion to manage intraoperative hypotension. Conversely, a substantial majority, 84 patients (84%), maintained stable haemodynamics without any vasopressor support. In patients requiring noradrenaline, the infusion was typically initiated early (between 3 to 9 minutes post-SAB) and discontinued within 25 to 60 minutes, indicating that the hypotensive episodes were generally transient and responsive to intervention. [Table 2].

Table 4: Comorbidities in patients with IHD

Comorbidity	Number of Patients	%
IHD without interventions pre-op:		
Hypertension (HT)	186	93.00
Diabetes Mellitus (DM)	64	32.00
Hyperlipidaemia	58	29.00
Angina	6	3.00
IHD with interventions pre-op:		
CABG/ Angioplasty	54	27.00

Among patients with IHD without prior interventions, the most common comorbidity was Hypertension (HT), affecting 186 patients (93%), followed by Diabetes Mellitus (DM) in 64 patients (32%), Hyperlipidaemia in 58 patients (29%), and Angina in 6 patients (3%) (Table4).In the group of patients with IHD who had undergone interventions pre-operatively, such as Coronary Artery Bypass Grafting (CABG) or Angioplasty, 54 patients (27%) were recorded.

DISCUSSION

This study explored the outcomes of using low-dose local anaesthetic for unilateral spinal anaesthesia in patients with a high cardiac risk due to ischemic heart disease. The results indicate that this technique is a safe option for such individuals. Additionally, the data suggest that employing this approach does not lead to an increase in mortality.

Cardiac output is primarily influenced by two variables: ejection fraction and heart rate. Ejection fraction itself is determined by myocardial contractility and end-diastolic filling. In patients with reduced myocardial contractility, cardiac output relies heavily on the left ventricular end-diastolic volume (LVEDV). For these individuals, an increase in heart rate may not effectively improve cardiac output.[8,9] In such cases, heightened sympathetic activity can lead to increased systemic vascular resistance (SVR), which may further compromise cardiac output. Spinal anaesthesia, by reducing sympathetic tone, leads to peripheral blood pooling and a subsequent decline in end-diastolic volume.[10,11] Since patients with low ejection fraction are preload-dependent, spinal anaesthesia can exacerbate the reduction in stroke volume and cardiac output. Prior research has shown that spinal block may reduce LVEDV by up to 19%, and this decline is a key contributor to decreased cardiac output in patients with impaired ejection fraction.[12] However, in patients with low cardiac index, administering spinal anaesthesia with a low dose of local anaesthetic has been associated with a smaller drop in mean arterial pressure. This is because lower doses tend to have a less pronounced effect on the sympathetic nervous system compared to traditional doses.[13]

In our observations, reduction in mean arterial pressures was less pronounced in patients with low ejection fraction compared to those with an ejection fraction greater than 40%. This outcome may be attributed to a greater increase in cardiac output in the low ejection fraction group, likely due to a more significant reduction in systemic vascular resistance (SVR) and afterload.[14] Management of hypotension following spinal anaesthesia typically involves intravenous fluid administration and the use of vasopressors. However, excessive fluid loading in patients with myocardial dysfunction can increase the risk of pulmonary edema.[15] For this reason, vasopressor use may be a safer alternative in these individuals. Ephedrine, a common vasopressor, increases heart rate and may have adverse effects in patients with compromised ejection fraction.[16] Alternatively, nor- epinephrine infusion during spinal anaesthesia has been shown to restore systolic blood pressure and enhance cardiac output without significantly affecting diastolic or mean arterial pressure.[17] Additionally, patients with left ventricular dysfunction are at increased risk for deep vein thrombosis and pulmonary embolism. In such cases, spinal anaesthesia may be preferred over general anaesthesia, as regional techniques are associated with a lower incidence of thromboembolic complications.[18]

Our study demonstrated that administering a spinal block using a low dose of bupivacaine provided effective anaesthesia in patients with high cardiac risk, with only minimal reductions in arterial pressure. In our study, Out of 200 patients, 32 (16%) required noradrenaline infusion to manage intraoperative hypotension. Conversely, a substantial majority, 168 patients (84%), maintained stable hemodynamics without any vasopressor support. In patients requiring noradrenaline, the infusion was typically initiated early (between 3 to 9 minutes post-SAB) and discontinued within 25 to 60 minutes, indicating that the hypotensive episodes were generally transient and responsive to intervention. This low incidence and short duration of vasopressor need underscore the overall favourable hemodynamic profile of unilateral spinal anaesthesia in this high-risk cohort. Notably, none of the patients reported intraoperative pain, which

may be attributed to altered or delayed drug pharmacokinetics commonly observed in individuals with cardiac dysfunction.

Chohan et al. investigated the hemodynamic effects of unilateral spinal anaesthesia in elderly patients with a preoperative ASA score of III or IV who were considered high-risk and undergoing hip fracture surgery. They employed a very low dose (1.8 mL) of 0.5% hyperbaric bupivacaine and found that this approach minimized the side effects typically associated with spinal anaesthesia, with hypotension mainly occurring within the first five minutes of the procedure.[19]

The retrospective design of our study represents a major limitation. Additionally, the exclusion of patients who declined surgery due to high perioperative risk may have introduced bias. The lack of a control group further limits the strength of our conclusions, as comparative analysis was not possible. Another shortcoming was the absence of a power analysis to support the statistical significance of our findings. Potential selection bias is also a concern, as inclusion was based on preoperative cardiac evaluations—some patients with ischemic heart disease may not have undergone such assessments and were therefore missed. Furthermore, the relatively small sample size should be noted. To address these limitations, prospective studies with larger patient populations are necessary to validate our results and better understand the long-term outcomes of low-dose unilateral spinal anaesthesia in this high-risk group.

CONCLUSION

In line with previous studies, we observed minimal changes in heart rate following spinal block with a low dose of local anaesthetic. This finding is particularly significant for patients with low ejection fraction, who have limited cardiac reserve. Based on our results, we conclude that spinal anaesthesia using a low dose of local anaesthetic is a safe and effective technique for performing total knee arthroplasty in this high-risk patient group.

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