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CASE SERIES **SPINAL ANESTHESIA**

Unilateral spinal anesthesia with fractionated low-dose hyperbaric ropivacaine and fentanyl can enhance hemodynamic control in high-risk lower limb surgeries: a case series

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ABSTRACT

Patients with compromised cardiopulmonary function and multiple comorbidities undergoing spinal anesthesia with conventional bolus dose face significant risks of hemodynamic instability due to sympathetic blockade. In such cases, the necessity of administering vasopressors and large volumes of intravenous fluids often leads to poor postoperative outcomes. However, unilateral spinal anesthesia utilizing fractionated low doses of cardio stable ropivacaine in its hyperbaric form when supplemented with fentanyl has demonstrated remarkable hemodynamic stability. We present five cases of high-risk patients who successfully underwent lower limb surgeries with this approach and with stable perioperative hemodynamics.

Keywords: Fractionated Spinal Anesthesia; Low Dose Hyperbaric Ropivacaine; Unilateral Spinal Anesthesia

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1. INTRODUCTION

It is a conventional technique to perform subarachnoid blocks with bolus doses of local anesthetics for lower limb surgeries, the sympathetic block often exceeds sensory block by 2-4 segments.[1, 2] High risk patients with impaired cardiovascular and pulmonary functions along with multiple systemic illnesses are prone to arterial hypotension after spinal anesthesia (SA) and therefore require large doses of vasopressors and intravenous fluids.[3, 4] However, they cannot tolerate fluid overload in which case their condition deteriorates further postoperatively. Consequently, fractionation of the spinal dose has been found to moderate hemodynamic changes while at the same time increasing the duration of action by minimally affecting respiratory mechanics and thereby making it especially appropriate for patients with compromised cardiovascular and pulmonary functions.[5,6]

Ropivacaine is a long-acting amide-type local anesthetic whose lipid solubility and affinity for myelinated motor fibers are limited than those seen with other amide type local anesthetic drugs, thus enabling better between sensory-motor differentiation.[7,8] Additionally, it presents a decreased risk of cardiotoxicity and neurotoxicity, rendering it an optimal choice for patients with cardiac illness. Baricity, among various factors, plays a crucial role in maintaining the spread of the anesthetic drug, with hyperbaric agents preferred in high-risk patients to minimize cardiovascular effects and ensure rapid recovery and patient satisfaction.[9,10]

Fentanyl, a synthetic opioid acting on mu receptors, is also effective as an adjuvant which enables subarachnoid block with lower doses of local anesthetic, thereby minimizing the side effects.[9] The addition of fentanyl complements the sensory blockade provided by ropivacaine and provides adequate intraoperative comfort while avoiding excessive sympathetic blockade and hemodynamic instability.[11,12]

This case series describes the successful anesthesia management of five high-risk patients with American Society of Anesthesiologists (ASA) physical status III-IV who underwent lower extremity surgery using unilateral spinal anesthesia with fractionated low-dose hyperbaric ropivacaine along with fentanyl as an adjuvant.

2. CASE SERIES

2.1. CASE 1

A 48-year-old man with 10 years of diabetes, developed a non-healing ulcer on the dorsum of his left foot that extended to the lateral part of the foot. He also suffered frrom bronchial asthma since childhood and had a mitral valve repaired ten years back. His basal heart rate (HR) was 160 beats per min, blood pressure (BP) 100/60 mmHg, and oxygen saturation (SpO_2) of 92% on room air. Evaluation revealed HbA1C of 12, FEV1/FVC ratio of 45%, and an electrocardiogram showing atrial fibrillation. Echocardiography demonstrated grossly dilated left and right atria with an ejection fraction (EF) of 30% and severe pulmonary artery hypertension. He was scheduled for below-knee amputation following cardiology and pulmonology evaluations. Treatment included digoxin 0.25 mg once daily (OD) and a stat dose of intra venous (iv) diltiazem 12.5 mg. Additionally, amiodarone 300 mg iv over 10 min, followed by infusion, and nebulization with budesonide and levosalbutamol were administered preoperatively. In the operating room (OR), radial artery catheterization was performed for invasive BP monitoring, and amiodarone infusion was continued with a defibrillator on standby. His intraoperative BP before giving SA was 110/69 mmHg and HR 120/min. Fractionated SA was administered with 1.8 mL of hyperbaric 0.75% ropivacaine and 25 of fentanyl (2.3 mL) in the left lateral decubitus position, achieving unilateral sensory block up to T10 in 3 min and motor block up to T12 in 9 min. At the end of the surgery, his BP was 115/67 mmHg and HR was 117 /min. The surgery lasted 90 min, during which the patient maintained stable hemodynamics without atrial fibrillation. His HR was maintained at 100-120 beats per min. Postoperatively, he was transferred to the intensive care unit for monitoring and further cardiac evaluation. The motor block lasted for 120 min and sensory block for 140 min from the time of administration of SA.

2.2. CASE 2

A 21-year-old female patient with right distal tibia fracture was scheduled for fracture reduction and fixation. A detailed preoperative anesthesia checkup was done. On examination, her pulse rate was 85/min, BP was 110/60 mmHg, SpO_2 was 87% on room air, and jugular venous pressure (JVP) was raised. Auscultation revealed a pansystolic murmur in the tricuspid area, and a bilateral wheez. She had a history of exertional breathlessness and frequent lower respiratory tract infections. Echocardiography showed a dilated right atrium and ventricle, displacement of the anterior tricuspid leaflet, severe tricuspid regurgitation, patent foramen ovale, right ventricular ejection fraction 15%, and left ventricular ejection fraction 50%. On evaluation by a cardiologist, she was diagnosed with Ebstein's anomaly and started on inj. Lasix 10 mg IV twice daily preoperatively. In the OR, all emergency drugs and a defibrillator were kept ready. IV fluids were administered according to maintenance requirements. Radial artery catheterization was performed for invasive BP monitoring. His intraoperative BP before giving SA was 116/82 mmHg and HR 98/min. Fractionated SA was administered with 2 mL of hyperbaric ropivacaine 0.75% and fentanyl 25 µg (2.5 mL) in the right lateral decubitus position. Following confirmation of a unilateral sensory block up to T10 in 3.5 min and motor block up to T12 in 8.5 min, the surgery commenced. At the end of the surgery, her BP was 116/79 mmHg and HR 83/min. The procedure lasted for 90 min, and the patient remained hemodynamically stable throughout. Subsequently, she was transferred to the Intensive Care Unit for monitoring and further management. The motor block lasted for 110 min and sensory block for 135 min from the time of administration of SA.

2.3. CASE 3

A 46-year-old male patient with a 13-year history of diabetes, dyslipidemia, and heart failure, presented with acute right lower limb ischemia due to cardio-embolic phenomenon. He had a history of pulmonary tuberculosis 10 years prior and was also a known case of poliomyelitis since childhood which resulted in a deformed right lower limb. He was scheduled for a right popliteal thrombectomy. His baseline HR was 95 beats per min, BP was 130/90 mmHg, and SpO_2 85% on room air. On auscultation, bilateral chest wheez and decreased air entry in the basal area were noted. Examination revealed severe thoracolumbar kyphoscoliosis toward the left side. Chest X-ray showed bilateral lower lung lobe consolidation, prominent bronchovascular markings, gross scoliosis toward the left, and pulmonary function tests revealed decreased functional vital capacity (FVC). Echocardiography showed an ejection fraction (EF) of 35%, pulmonary artery hypertension, and severe mitral regurgitation. Color Doppler revealed absent flow in the popliteal artery. Cardiology and pulmonology evaluations were performed. He was started on Lasix 20 mg BID, glyceryl trinitrate 2.6 mg OD, and levoalbuterol and budesonide nebulization. In the OR, radial artery catheterization was performed for invasive BP monitoring. His intraoperative BP before giving SA was 120/84 mmHg and HR 103/min. Fractionated dose SA was administered with 1.5 mL of 0.75% ropivacaine and 25 µg fentanyl in the right lateral decubitus position. Unilateral sensory block up to T10 in 3.5 min and motor block up to T12 in 7.5 min was achieved and surgery was allowed to proceed. HR above baseline and euvolemia were maintained throughout the intraoperative period. At the end of surgery his BP was 125/90 mmHg and HR was 89/min. A phenylephrine bolus dose of 20 µg was administered once. The surgery lasted for 80 min, and the patient was shifted to the intensive care unit for monitoring and further management. The motor block lasted for 125 min and sensory block for 145 min from the time of administration of SA.

2.4. CASE 4

A 60-year-old female, hypertensive, diabetic, with morbid obesity (BMI = 48 kg/m²), and a history of chronic toddy drinking, was scheduled for debridement of burns wounds over the right thigh with split skin grafting. She is a known case of heart failure with reduced ejection fraction, secondary to dilated cardiomyopathy and post-scrub typhus myocarditis. Additionally, she had a history of obstructive sleep apnea. Her baseline HR was 78/min, BP was 130/80 mmHg, and SpO_2 was 95% on room air. Upon evaluation, serum bilirubin was 3.5, chest X-ray showed cardiomegaly with a prominent aortic knuckle, and echocardiography revealed akinetic distal half of the interventricular septum, severe left ventricular systolic dysfunction with an ejection fraction (EF) of 20%. Cardiology evaluation was conducted, and she was initiated on losartan 25 mg OD, spironolactone 50 mg OD, and digoxin 0.125 mg OD. Intraoperative invasive BP (IBP) monitoring was performed after catheterizing the radial artery. His intraoperative BP before giving SA, was 130/88 mmHg and HR 95/min. Fractionated SA was administered with 2 mL of hyperbaric 0.75% ropivacaine and 25 µg of fentanyl (total-2.5 mL) in the right lateral decubitus position. Sensory block up to T10 in 3 min and motor block up to T12 in 8 min was achieved and surgery was allowed to proceed. At the end of surgery his BP was 125/95 mmHg and HR was 95/min. Phenylephrine 20 µg bolus dose was administered twice to maintain BP. The surgery lasted for 80 min, and the patient was kept in the high dependency unit for one day. Her postoperative course was uneventful. The motor block lasted for 120 min and sensory block for 140 min from the time of administration of SA.

2.5. CASE 5

A 51-year-old male patient was posted for wide local excision of a synovial sarcoma of his left knee and split skin grafting. He had already undergone 4 cycles of External Beam Radiation Therapy (EBRT). He was a known case of coronary artery disease and chronic kidney disease. Hypertension and diabetes were present for 12 years, with poor control despite using regular medication. A whole-body PET-CT revealed liver metastasis in the right lobe, and examination showed anasarca secondary to hypoalbuminemia. His baseline HR was 95/min, and BP was 190/110. On evaluation, his hemoglobin was 8 gm/dl, HbA1C was 10, serum creatinine was 2.5, and serum albumin was 1.6. Echocardiography revealed global hypokinesia of the left ventricle, severe left ventricular systolic and diastolic dysfunction with an ejection fraction of 30%. Preoperative albumin correction was done for 3 days. Cardiology and nephrology evaluations were done. His diabetes and hypertension were controlled on medication. One unit of packed red blood cells (PRBC) was transfused preoperatively, and the surgery was scheduled one week later. In the OR, the left radial artery was catheterized for invasive BP monitoring and fluid restriction was maintained at a rate of 40 mL/hr. His intraoperative BP before giving SA was 140/99 mmHg and HR 110/min. Fractionated SA was administered using 1.7 mL of hyperbaric 0.75% ropivacaine and 20 µg of fentanyl (total 2.1 mL) in the left lateral decubitus position. Unilateral sensory block was achieved up to T10 in 2.5 min and motor block up to T12 in 7 min, and surgery was allowed to proceed. At the end of the surgery, his BP was 129/97 mmHg and HR was 97/min. and the surgery lasted for 75 min. After completion of the surgery, the patient was shifted to the recovery room with stable vitals and the postoperative period was uneventful. The motor block lasted for 100 min and sensory block for 130 min from the time of administration of SA.

All these high-risk patients were administered fractionated doses of SA by giving two-thirds of the drug initially, followed by one-third of the drug after 90 seconds.

3. DISCUSSION

High-risk patients undergoing lower limb surgeries can benefit from fractionated low doses of unilateral SA with hyperbaric ropivacaine along with fentanyl as an adjunct more stable hemodynamic control without the risks associated with conventional bolus dosing.

In patients with cardiac dysfunction, dependence on left ventricular end-diastolic volume for maintaining stroke volume and cardiac output exacerbates the effect of sympathectomy due to SA. This leads to exaggerated post-spinal hypotension due to diastolic dysfunction and reduced baseline cardiac output, coupled with an inability to augment output following SA.

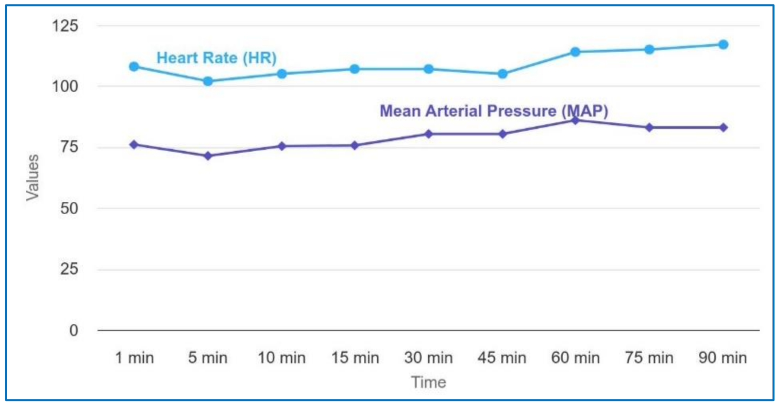

Figure 1: Intraoperative HR and MAP changes in case *1*

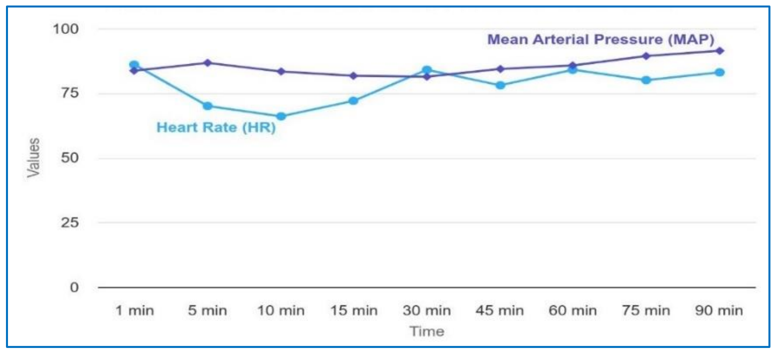

Figure 2: Intraoperative HR and MAP changes in case 2

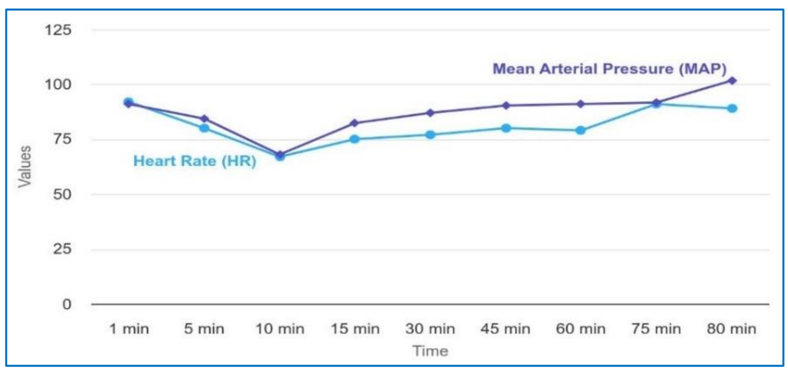

Figure 3: Intraoperative HR and MAP changes in case 3

Fractionating the spinal dose results into less drug spreading through a smaller surface area initially, this causes relatively slow sympathetic nervous system inhibition compared to bolus administration. Additionally, subsequent fraction of the same drug tends to concentrate within the blocked area thus avoiding further vasodilation which reduces need for the vasopressors and intravenous fluids.[2] The prolonged duration may be attributed to the action of a second fractional drug dose on the already blocked area. Our SA technique was similar to the study conducted by Kaniyil et al. where a 90-sec interval was utilized between the two fractions of SA.[11] In patients with compromised cardiac function, left ventricular end–diastolic volume is crucial for maintaining stroke volume and cardiac output.[12] Fractionated SA helps in minimizing abrupt changes in sympathetic tone and venous return, thus reducing the risk of exaggerated hypotension. Cardiac output is dependent on stroke volume and HR. The fractionated approach, by mitigating drastic reductions in systemic vascular resistance, helps in maintaining a more stable cardiac output and stroke volume, which is particularly important in high-risk patients with compromised cardiac function.

Ropivacaine is the least cardiotoxic drug than other choices of amide local anesthetics, and therefore a better option for patients with cardiac disease.[13] Predictable spread and adequate block height are facilitated by using hyperbaric ropivacaine while preventing cardiovascular side effects to some extent.[14] These properties help to maintain hemodynamic stability in high-risk patients undergoing surgery. The addition of fentanyl increases the effectiveness of subarachnoid block with smaller doses of local anesthetic reducing side-effects. This is necessary since fentanyl is analgesic and complements the sensory blockade produced by ropivacaine thus maintaining appropriate intraoperative comfort without inducing excessive sympathetic blockade as well as hemodynamic instability.

Our case series indicates that the surgical procedure was done on high-risk patients who already had co-existing cardiovascular and respiratory co-morbids, such as atrial

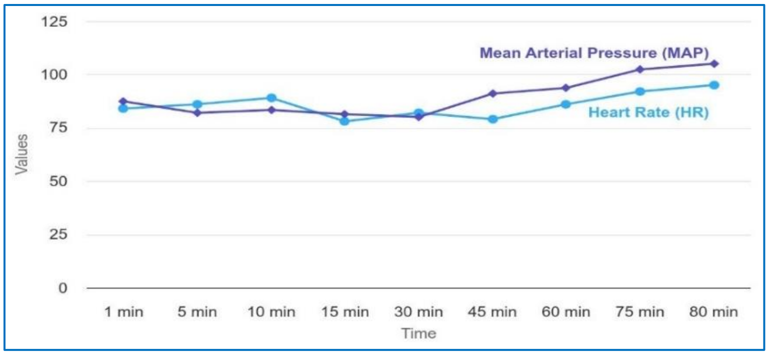

Figure 4: Intraoperative HR and MAP changes in case 4

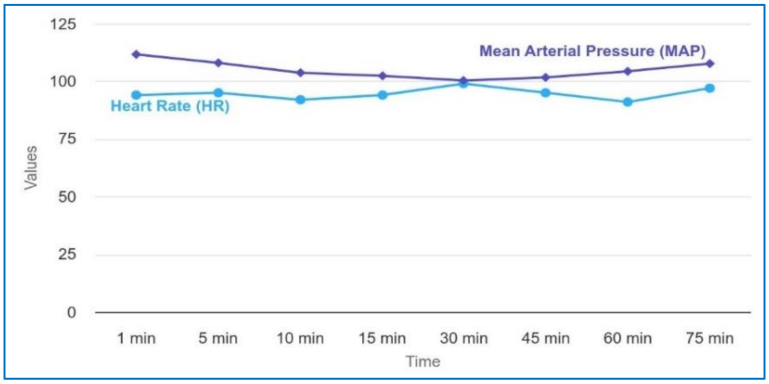

Figure 5: Intraoperative HR and MAP changes in case 5

fibrillation, pulmonary artery hypertension and severe ventricular dysfunction. Three out of the five patients were on anticoagulant therapy, and their surgical procedures were meticulously scheduled after implementing a bridging therapy strategy, in accordance with the guidelines outlined by Macfarlane et al.[15] and Ashken & West.[16] This case series reveals that fractionated dosing of SA not only reduces the incidence of hypotension but also offers enhanced predictability in achieving optimal block levels. This finding contrasts with previous studies that primarily focused on the reduction of hypotensive episodes alone. Fractionated doses provide a finer control over the block's extent and intensity, allowing for tailored anesthesia that matches the patient's hemodynamic status more precisely.

An intriguing finding from our case series is the synergistic effect of fentanyl with hyperbaric ropivacaine, which appears to stabilize hemodynamics beyond what would be expected from the local anesthetic alone. While fentanyl is known to enhance analgesia, our data suggest it may also play a role in modulating sympathetic tone, thereby contributing to improved cardiovascular stability during surgery. This effect has not been widely reported in existing literature and opens new avenues for understanding the interplay between opioid adjuncts and local anesthetics.

Our case series suggests that fractionated low-dose SA may significantly reduce the need for postoperative vasopressor use. This finding is noteworthy, as it implies that not only does this technique manage intraoperative hemodynamics effectively, but it also potentially reduces postoperative complications associated with vasopressor use, such as arrhythmias and excessive fluid resuscitation. Comprehensive preoperative evaluation and risk stratification is needed to identify subjects who might benefit from modified anesthetic techniques.[17] The need for invasive BP monitoring like radial arterial cannulation and vigilant perioperative monitoring can help to detect and treat early hemodynamic changes.

Incorporating advanced cardiac function monitoring techniques like using intraoperative echo probe in high-risk cardiac patients undergoing surgery under SA helps in monitoring cardiac function and hemodynamics. They keep a track of changes in cardiac performance, guide fluid and medication management, detect complications like valvular dysfunction or fluid accumulation, and assess the impact of anesthesia and surgical stress. This continuous feedback allows to better tailor anesthetic management and anticipate hemodynamic responses.

4. LIMITATIONS

The limitations of our case series are the need of extreme care and vigilance in high-risk patients with severe cardiovascular instability, on high vasopressor support preoperatively, neurological conditions or spinal deformities, patients with infections at the injection site, coagulation disorders, including those on anticoagulant therapy, who were not bridged, anatomical variations or previous spinal surgeries, severe hypovolemia and severe sepsis. Additionally, the need for patient cooperation and proper positioning introduced another layer of complexity, as anxious, non-cooperative patients might increase procedural risks.

5. CONCLUSION

For high-risk surgical patients, particularly those with compromised cardiac function and pulmonary function a fractionated low-dose unilateral spinal anesthesia with hyperbaric ropivacaine and fentanyl offers a promising alternative to traditional bolus dosing. This approach demonstrates efficacy in maintaining stable perioperative hemodynamics, while minimizing the risks associated with sympathetic blockade and fluid overload. Adopting fractionated dosing techniques to minimize the need for vasopressors and associated complications may lead to improved postoperative outcomes and reduced recovery times. Future studies should compare the novel findings of this fractionated dosing technique with traditional methods in diverse patient populations to validate these observations and refine anesthetic practices.

6. Data availability

The numerical data generated during this research is available with the authors.

7. Acknowledgement

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8. Conflict of interest

The study utilized the hospital resources only, and no external or industry funding was involved.

9. Authors' contribution

PR: Concept, Design, Literature search, Data acquisition, Manuscript preparation

UG: Concept, Design, Literature search, Data analysis, Manuscript editing and Guarantor

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