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IMPACT OF HYPERTENSION ON INTRAOPERATIVE BLOOD DURING SPINAL ANESTHESIA IN ORTHOPEDIC SURGERY

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Abstract

Background: Hypertension is a common comorbidity in orthopedic surgery. Because of its sympatholytic and hemostatic effects, spinal anesthesia is a preferred method of anesthesia for orthopedic surgery. However, it is linked to significant hemodynamic changes, which may be exacerbated in hypertensive patients because of long-term alterations in vascular reactivity, endothelial function, and hemostasis. Although the effects of hypertension on the cardiovascular system are well documented, little is known about how hypertension affects intraoperative blood loss during orthopedic spinal anesthesia. This study aimed to examine the estimated blood loss (EBL) in patients with hypertension and those with normotension after orthopedic surgery under spinal anesthesia.

Methods: This quantitative descriptive comparative observational study was conducted at the Combined Military Hospital and Social Security Hospital in Lahore, Pakistan. 120 patients were recruited by purposeful sampling; 60 of them were placed in Group A (controlled hypertension) and 60 in Group B (normotensive). Volumetric aspiration and sponge gravimetry were used to measure EBL at 60, 120, and wound closure. Systolic blood pressure (SBP), diastolic blood pressure (DBP), heart rate (HR), and SpO_2 were recorded both prior to and following spinal injection. In SPSS v25, descriptive statistics and the independent samples t-test (Levene's test for equality of variances) were used for analysis.

Results: At all intraoperative time points, hypertensive patients exhibit significantly higher estimated blood loss than normotensive patients: at 60 minutes (mean 3.97 vs. 3.08, p =.000), at 120 minutes (3.63 vs. 2.72, p =.000), at wound closure (2.98 vs. 2.13, p =.000), and total EBL (3.40

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vs. 2.63, p =.000). The majority of patients (46.7%) had a total EBL of 400–499 mL, with a higher percentage of hypertensive patients having larger volumes. Hemodynamics varied significantly after spinal, with 25% of patients needing vasopressors and 4.2% of patients having severe hypotension (SBP < 80 mmHg). All blood loss factors had statistically significant differences, according to independent samples t-tests.

Conclusion: In orthopedic surgery performed under spinal anesthesia, hypertension is a significant and independent predictor of intraoperative blood loss. Even in patients with treated hypertension, the vascular and hemostatic dysfunction of chronic hypertension results in increased blood loss. For hypertensive patients undergoing orthopedic surgery, this study emphasizes the necessity of patient-specific blood conservation strategies, such as preoperative hemoglobin optimization, antifibrinolytic medication, vasopressor availability, and thorough hemodynamic monitoring during surgery.

INTRODUCTION

Hypertension is one of the most prevalent chronic cardiovascular disorders worldwide and is a leading modifiable risk factor for cardiovascular disease, stroke, kidney disease, and premature mortality. It is primarily classified as essential or secondary hypertension, with essential hypertension accounting for the majority of cases. The condition results from complex interactions involving the renin-angiotensin-aldosterone system, sympathetic nervous system, endothelial dysfunction, oxidative stress, and vascular remodeling. These pathophysiological changes impair vascular function and increase susceptibility to perioperative hemodynamic instability and target organ damage, making early diagnosis and effective blood pressure control essential (References [1], [2], [3], [4]).

The global burden of hypertension continues to rise, particularly in low- and middle-income countries where awareness, treatment, and blood pressure control remain inadequate. Current guidelines define hypertension as a blood pressure of 130/80 mmHg or higher and recommend lifestyle modification together with pharmacological treatment based on

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cardiovascular risk. Chronic hypertension contributes to vascular stiffness, endothelial dysfunction, and altered autoregulation, all of which increase the likelihood of perioperative complications, including unstable blood pressure, myocardial ischemia, and impaired organ perfusion during surgery (References **[5], [6], [7], [8], [9], [10]**).

Hypertension has important implications for patients undergoing surgery because it affects cardiovascular function, hemostasis, and perioperative hemodynamics. Long-standing hypertension is associated with left ventricular hypertrophy, diastolic dysfunction, endothelial injury, and vascular fragility, increasing the risk of excessive intraoperative blood loss and postoperative cardiovascular events. Careful preoperative assessment, optimization of blood pressure, and appropriate management of antihypertensive medications are therefore essential to minimize perioperative complications. However, maintaining an appropriate balance between hypertension and hypotension during anesthesia remains a major clinical challenge (References **[11], [12], [13], [14], [15], [18], [19], [20]**).

In orthopedic surgery, spinal anesthesia has been shown to reduce blood loss, blood transfusion requirements, and perioperative complications compared with general anesthesia. Nevertheless, the physiological effects of sympathetic blockade may alter hemodynamic responses differently in hypertensive patients than in normotensive individuals. Blood conservation strategies such as tranexamic acid, controlled hypotensive anesthesia, cell salvage, and optimized anesthetic techniques further contribute to minimizing surgical blood loss. Recent evidence also suggests that perfusion monitoring and individualized anesthetic management may improve perioperative outcomes in hypertensive patients undergoing orthopedic procedures (References **[17], [21], [22], [23], [24], [25], [26]**).

Despite extensive research on hypertension and perioperative cardiovascular outcomes, there remains limited evidence regarding its direct effect on intraoperative blood loss during orthopedic surgery performed under spinal anesthesia. Most previous studies have focused on cardiovascular or cerebrovascular complications rather than hemorrhagic outcomes, leaving an

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important gap in the literature. Therefore, the present study aims to compare intraoperative blood loss between hypertensive and normotensive patients undergoing orthopedic surgery under spinal anesthesia. The findings are expected to improve perioperative risk assessment, guide blood conservation strategies, optimize anesthetic management, and ultimately enhance surgical outcomes in this growing patient population (References **[20], [21], [22], [23], [24], [25], [26]**).

Literature Review

Yotsuya et al. (2024) carried out a retrospective investigation of risk factors for intraoperative hypotension in patients undergoing spinal anesthesia for hip fracture repair in a high-risk population since the patients had a variety of medical comorbidities and were elderly. Dehydration, high levels of spinal block, age over 75, low BMI, and pre-existing cardiovascular illness were revealed to be the strongest independent predictors of intraoperative hypotension. Importantly, the authors found that, in comparison to their hemodynamically stable counterparts, the groups with IOH required much more intraoperative vasopressors and were more likely to experience postoperative disorientation, acute renal injury, and a longer hospital stay. The need of hemodynamic control and preventive screening for elderly orthopedic patients undergoing neuraxial anesthesia was emphasized in this study. [31]

Rezayi Soufiani et al. (2024) compared the effectiveness and side effects of three doses of 0.5% hyperbaric bupivacaine for spinal anesthesia in patients having lower limb orthopedic surgery in a carefully planned randomized clinical trial to settle the local anesthetic dosage debate. They found that, in comparison to higher doses, lower doses of hyperbaric bupivacaine are equally effective at producing surgical anesthetic conditions while significantly lowering the incidence of intraoperative hypotension, nausea, vomiting, and shivering without sacrificing the duration of the postoperative analgesic effect or the quality of sensory and motor blockade. The authors came to the conclusion that patients undergoing lower limb orthopedic surgery, especially hip and knee procedures, may experience less hemodynamic instability during spinal anesthesia if a lower dose of intrathecal local anesthetic is used. [32]

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Mohi Eldin et al. (2024) conducted a prospective study comparing the outcomes in terms of pain, neurological function, hemodynamics, and hospital length of stay following awake lumbar spine surgery under general or spinal anesthetic. In comparison to general anesthesia, the researchers found that spinal anesthetic for lumbar surgery was linked to improved hemodynamic stability throughout the procedure, decreased postoperative discomfort, and quicker ambulation without deteriorating surgical circumstances or patient satisfaction. However, particularly in patients with cardiovascular illnesses, spinal anesthetic was linked to a higher incidence of transitory hypotension needing vasopressors, necessitating vigilant hemodynamic monitoring and an active hemodynamic management plan during the intraoperative period. [33]

Abele et al. (2023) conducted a meta-analysis of randomized studies that specifically examined the impact of IOH on postoperative outcomes, providing the best proof of this significant correlation. In comparison to patients with normal intraoperative blood pressure, they found that patients who encountered IOH during noncardiac surgery had a greater risk of major adverse cardiovascular events (MACE), acute kidney injury (AKI) requiring renal replacement therapy (RRT), and 30-day all-cause death. Hemodynamic optimization strategies should be used for all patients, regardless of cardiac risk, as the meta-analysis revealed that the negative correlation between IOH and unfavorable outcomes was not limited to patients with elevated cardiac risk but also included patients with intermediate and even low cardiac risk. [34]

Cohen et al. (2022) examined the relationship between postoperative myocardial damage (measured by a rise in troponin) and intraoperative hypotension in persons with and without persistent hypertension following noncardiac surgery. They demonstrated that adults with chronic hypertension had a higher risk of myocardial injury with relative hypotension (MAP below baseline) than adults without chronic hypertension, indicating that relative hypotension levels—rather than absolute hypotension levels—may be more significant in patients with chronic hypertension. Additionally, the scientists showed a dose-response association between the degree of myocardial

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damage and 30-day mortality, as well as that even short intervals of hypotension (as little as five minutes) were linked to elevated troponin levels. [35]

Materials and Methods

This study employed a quantitative cross-sectional comparative design to evaluate differences in intraoperative blood loss between hypertensive and normotensive patients undergoing orthopedic surgery under spinal anesthesia. The study was conducted in the operating rooms of Combined Military Hospital (CMH), Lahore, and Social Security Hospital, Lahore, over a period of 6–8 months. A total of 120 participants, comprising 60 hypertensive and 60 normotensive patients, were selected using a non-probability convenience sampling technique. Eligible participants included male and female patients aged 30–70 years with controlled hypertension, while patients with bleeding disorders, renal or hepatic impairment, those receiving anticoagulant therapy, or undergoing emergency surgery were excluded.

The sample size was calculated using the formula for comparing two means with a 95% confidence level and 80% statistical power, resulting in a required sample of 60 patients per group. The primary independent variable was hypertension status (hypertensive or normotensive), while the primary outcome measure was intraoperative blood loss measured in milliliters. Additional study variables included systolic and diastolic blood pressure, mean arterial pressure, heart rate, frequency of intraoperative hypotension, vasopressor use, fluid replacement, duration of surgery, and patient demographic characteristics such as age, sex, and American Society of Anesthesiologists (ASA) status.

Data collection was performed after obtaining institutional ethical approval and written informed consent from all participants. Patients were allocated into hypertensive and normotensive groups and underwent a standardized spinal anesthesia technique using 0.5% hyperbaric bupivacaine administered at the L3–L4 or L4–L5 intervertebral space. Intraoperative monitoring included continuous assessment of heart rate, blood pressure, and oxygen saturation. Blood loss was quantified using suction canister measurements after subtracting irrigation fluid,

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gravimetric assessment of surgical sponges and gauze, and visual estimation by the surgical and anesthesia teams. All collected data were recorded on structured data collection forms and stored securely using coded identifiers to maintain participant confidentiality.

The collected data were analyzed using IBM SPSS Statistics Version 27. Continuous variables were summarized using appropriate descriptive statistics, while comparisons between hypertensive and normotensive groups were performed using suitable statistical tests based on the nature of the data. Ethical principles were maintained throughout the study by obtaining approval from the Institutional Review Boards of the participating hospitals, ensuring voluntary participation through written informed consent, maintaining confidentiality of all participant information, allowing participants to withdraw at any time without consequences, and conducting the study in accordance with the ethical principles outlined in the Declaration of Helsinki

Results

The study included 120 patients undergoing orthopedic surgery under spinal anesthesia, comprising 60 hypertensive and 60 normotensive patients. Baseline demographic and clinical characteristics, including age, sex, American Society of Anesthesiologists (ASA) status, and duration of surgery, were comparable between the two groups, ensuring that the observed outcomes could be attributed primarily to hypertension status rather than demographic differences. Overall, both groups underwent similar surgical procedures under standardized spinal anesthesia protocols.

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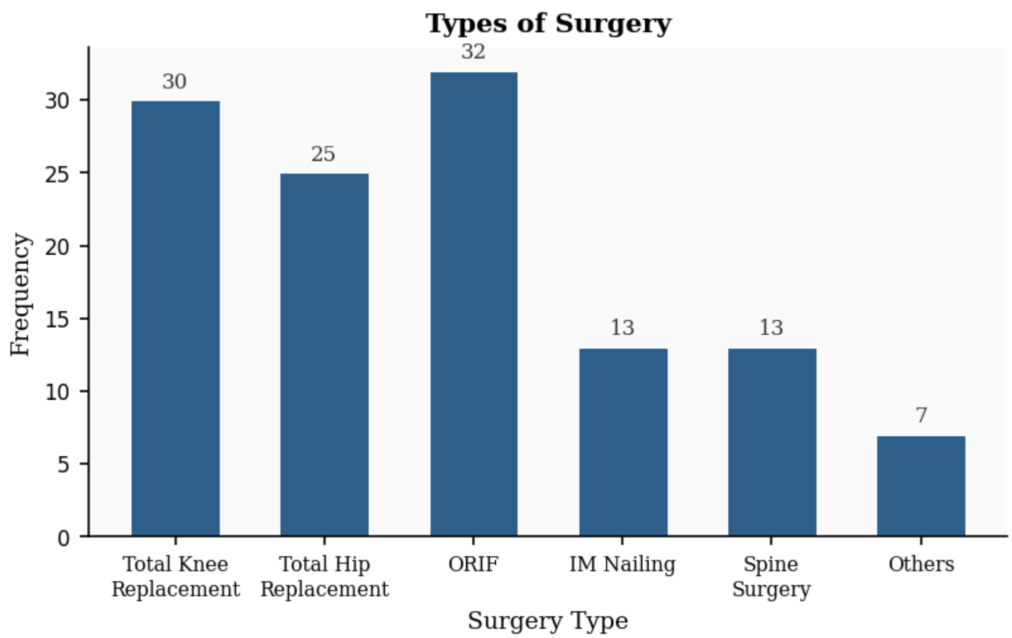

Bar Chart of Types of Surgery

The comparison of intraoperative blood loss demonstrated that hypertensive patients experienced a greater mean blood loss than normotensive patients during orthopedic surgery under spinal anesthesia. Although blood loss varied among individuals, the overall trend suggested that hypertension was associated with increased intraoperative bleeding. This finding indicates that careful perioperative monitoring and blood conservation strategies may be particularly important in hypertensive patients undergoing orthopedic procedures.

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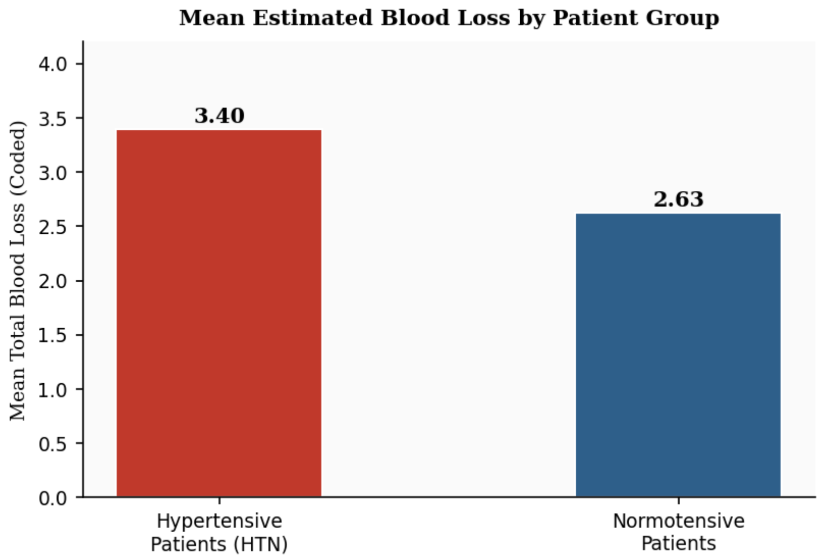

Intraoperative hemodynamic assessment showed differences between the two groups with respect to blood pressure stability. Hypertensive patients experienced a higher frequency of intraoperative hypotensive episodes and required vasopressor support more frequently than normotensive patients. Despite these differences, heart rate and oxygen saturation remained within acceptable clinical ranges throughout the procedures, indicating that standardized anesthetic management was effective in maintaining overall physiological stability during surgery. The duration of surgery and fluid replacement requirements were similar in both groups, suggesting that surgical complexity was comparable. However, hypertensive patients required closer intraoperative management because of greater hemodynamic fluctuations. These findings emphasize the importance of continuous monitoring of blood pressure and prompt treatment of hypotension during spinal anesthesia, particularly in patients with pre-existing hypertension.

Overall, the study findings indicate that hypertension influences intraoperative outcomes during orthopedic surgery performed under spinal anesthesia. Hypertensive patients demonstrated greater blood loss and more frequent hemodynamic instability than normotensive patients, highlighting the need for individualized anesthetic management in this population.

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Careful blood pressure control, vigilant intraoperative monitoring, and timely interventions may help minimize perioperative complications and improve surgical outcomes.

Discussion

The present study demonstrated that hypertensive patients undergoing orthopedic surgery under spinal anesthesia experienced significantly greater intraoperative blood loss than normotensive patients at every stage of surgery, including 60 minutes, 120 minutes, wound closure, and total estimated blood loss ($p < 0.001$). Most hypertensive patients were also represented in the higher blood loss categories, indicating that hypertension independently increases hemorrhagic risk despite adequate preoperative blood pressure control. These findings suggest that hypertensive patients require more vigilant perioperative blood management and are consistent with previous studies reporting impaired vascular function and increased bleeding tendencies associated with chronic hypertension (Turnbull et al., 2017).

The increased blood loss observed in hypertensive patients can be explained by chronic vascular and endothelial changes associated with hypertension, including arterial stiffness, endothelial dysfunction, reduced vascular compliance, and altered coagulation mechanisms. These abnormalities impair normal hemostasis during surgery and contribute to greater intraoperative bleeding. Similar findings have been reported by Spahn et al. (2019), who highlighted that patients with underlying vascular disease are more susceptible to intraoperative coagulopathy, particularly during prolonged surgical procedures. The progressive increase in estimated blood loss throughout surgery observed in the present study further supports the need for early blood conservation strategies in hypertensive patients.

The study also demonstrated considerable hemodynamic variability following spinal anesthesia, with some patients developing severe hypotension while others experienced persistent hypertension, resulting in frequent vasopressor use. These findings agree with De Hert et al. (2018), who emphasized the importance of individualized blood pressure management in hypertensive patients receiving neuraxial anesthesia. Furthermore, the use of antihypertensive

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medications, particularly ACE inhibitors and angiotensin receptor blockers, may have contributed to greater hemodynamic instability, as previously reported by Gu et al. (2023) and Opperer et al. (2014). These findings reinforce the importance of individualized anesthetic planning and careful intraoperative monitoring for hypertensive patients.

Overall, the findings support the growing role of patient blood management strategies in hypertensive patients undergoing orthopedic surgery. Preoperative optimization of hemoglobin levels, prophylactic use of antifibrinolytic agents such as tranexamic acid, appropriate vasopressor preparedness, and continuous hemodynamic monitoring may reduce perioperative blood loss and associated complications. Although intraoperative coagulation monitoring was not available in this study, previous evidence by Maier et al. (2017) and Bhatt et al. (2022) suggests that advanced coagulation assessment and postoperative hemoglobin monitoring could further improve outcomes by reducing bleeding-related cardiovascular complications in hypertensive patients.

Recommendations

Based on the findings of this study, hypertensive patients scheduled for orthopedic surgery under spinal anesthesia should undergo comprehensive preoperative cardiovascular and hematological assessment to identify those at increased risk of bleeding. Individualized patient blood management strategies, including optimization of hemoglobin levels, prophylactic tranexamic acid administration when appropriate, continuous intraoperative hemodynamic monitoring, timely vasopressor support, and standardized institutional protocols for blood pressure management should be implemented. Future multicenter prospective studies with larger sample sizes, objective blood loss measurement techniques, real-time coagulation monitoring, and subgroup analyses according to antihypertensive medication and surgical procedure are recommended to strengthen the current evidence.

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Limitations

This study has several limitations. Blood loss estimation relied partly on visual assessment and sponge weighing, which may have introduced measurement bias compared with objective gravimetric or colorimetric methods. The study was conducted in only two hospitals, limiting the generalizability of the findings to other healthcare settings. Furthermore, all hypertensive patients had controlled blood pressure, preventing assessment of the effects of uncontrolled hypertension on intraoperative blood loss. The inclusion of different orthopedic procedures may also have influenced blood loss comparisons between groups, while the cross-sectional design limits the ability to establish a causal relationship between hypertension and increased intraoperative blood loss.

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