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Impact of Ultrasound-Guided Regional Anesthesia on Pain Management in Orthopedic Trauma Surgery

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Abstract **Original Research Article**

Background: Effective pain management is critical in orthopedic trauma surgery to enhance recovery, reduce opioid consumption, and minimize complications. Ultrasound-Guided Regional Anesthesia (UGRA) has emerged as a promising technique for improving postoperative outcomes. This study aimed to evaluate the impact of UGRA on pain control, opioid consumption, postoperative complications, and patient satisfaction compared to standard pain management. ***Methods:*** This prospective, comparative study was conducted with 60 patients undergoing orthopedic trauma surgery, divided into two groups: Group A (UGRA, n = 30) and Group B (Control, n = 30) at the Department of Anaesthesia, Analgesia, and Intensive Care Medicine, Bangabandhu Sheikh Mujib Medical University (BSMMU), Dhaka, Bangladesh. Data on pain scores (VAS), opioid consumption, time to first ambulation, postoperative complications, patient satisfaction, and length of hospital stay were collected and analyzed. Statistical comparisons were made using appropriate tests. ***Results:*** UGRA significantly reduced pain scores at 1, 6, and 24 hours post-surgery ($p < 0.001$), with lower opioid consumption (10 ± 5 mg vs. 25 ± 8 mg, $p < 0.001$). Time to first ambulation was shorter in Group A (24 ± 4 hours vs. 30 ± 5 hours, $p < 0.001$). UGRA was associated with fewer complications, including nausea/vomiting (6.7% vs. 26.7%, $p = 0.034$) and respiratory depression (0% vs. 10%). Patient satisfaction was higher in the UGRA group (4.8 ± 0.4 vs. 3.5 ± 0.6, $p < 0.001$), with a shorter hospital stay (4 ± 1 days vs. 6 ± 2 days, $p < 0.001$). ***Conclusion:*** UGRA provides superior pain control, reduces opioid consumption and complications, and enhances patient satisfaction in orthopedic trauma surgery, contributing to faster recovery and shorter hospital stays.

Keywords: Ultrasound-Guided Regional Anesthesia, pain management, opioid consumption, orthopedic trauma, postoperative complications.

INTRODUCTION

Pain management in orthopedic trauma surgery is a significant challenge due to the severity and complexity of the procedures involved [1]. Inadequate pain control can lead to delayed recovery, prolonged hospital stays, chronic pain syndromes, and increased reliance on opioid analgesics, all of which pose risks to both patients and healthcare systems [2]. Traditional pain management methods, such as general anesthesia and systemic opioid administration, are commonly used but often result in undesirable side effects, including nausea, vomiting, respiratory depression, and the potential for opioid addiction [3]. As a response to these challenges, regional anesthesia has emerged as an effective alternative for perioperative and postoperative pain management, especially in orthopedic trauma cases [4].

In recent years, Ultrasound-Guided Regional Anesthesia (UGRA) has gained popularity due to its precision, safety, and effectiveness [5]. By using real-time ultrasound imaging, anesthesiologists can visualize nerve structures and guide the administration of local anesthetics with high accuracy [6]. This reduces the risk of complications, such as accidental nerve or vascular injury, while enhancing the efficacy of nerve blocks [7]. UGRA allows for the precise deposition of anesthetic agents around targeted nerves, offering superior pain relief compared to traditional landmark-based techniques, which rely on anatomical estimates that can be less reliable and prone to error [8].

Orthopedic trauma surgeries, including those involving fractures of the extremities, pelvis, and spine, are particularly suited to regional anesthesia [9]. These procedures are often associated with significant postoperative pain due to the invasive nature of the interventions [10,11]. Effective pain management is critical for improving surgical outcomes, promoting early mobilization, reducing the risk of complications such as deep vein thrombosis (DVT) and pulmonary embolism, and shortening the overall recovery period [12]. Additionally, UGRA has the potential to reduce opioid requirements for postoperative pain control, thus lowering the incidence of opioid-related side effects and complications [13]. Given the ongoing opioid crisis, UGRA aligns well with enhanced recovery after surgery (ERAS) protocols, which focus on multimodal analgesia and minimizing opioid use [14].

Multiple studies have demonstrated the efficacy of UGRA in improving pain outcomes in orthopedic surgeries [15]. Research consistently shows that UGRA provides better pain control, reduces opioid consumption, and leads to faster recovery compared to general anesthesia or traditional landmark-based regional anesthesia techniques [16]. In the context of orthopedic trauma, where patients often experience significant pain both before and after surgery, the use of UGRA can greatly enhance patient comfort and satisfaction [17]. Additionally, UGRA is associated with a lower incidence of postoperative complications, such as respiratory depression and cognitive dysfunction, which are more common with general anesthesia, especially in elderly or frail patients [18].

Beyond its clinical benefits, UGRA offers substantial safety advantages [19]. Ultrasound guidance allows anesthesiologists to visualize critical anatomical structures, such as blood vessels and nerves, reducing the risk of accidental injury during needle insertion [20]. This precision is particularly important in trauma patients, whose anatomy may be altered by fractures or previous surgeries, making traditional landmark-based techniques more challenging [21]. Furthermore, ultrasound guidance enables real-time assessment of local anesthetic spread, ensuring the effectiveness of the nerve block and reducing the need for additional injections or adjustments [22].

Despite its clear benefits, the widespread adoption of UGRA in orthopedic trauma surgery faces some challenges. One of the main barriers is the learning curve associated with the technique, as proficiency in ultrasound-guided procedures requires specialized training and experience, which may not be readily available in all healthcare settings [23]. Additionally, the cost of acquiring and maintaining ultrasound equipment can be a limitation, particularly in resource-constrained environments [24]. However, as the benefits of UGRA become more widely recognized, efforts are being made to expand access to training and resources, making this advanced form of pain management more available.

This study aimed to evaluate the impact of ultrasound-guided regional anesthesia on pain management in orthopedic trauma surgery, with a focus on its ability to improve pain control, reduce opioid consumption, and enhance patient outcomes. By comparing UGRA with traditional pain management techniques, the research seeks to provide valuable insights into its advantages and its potential role in optimizing pain management in orthopedic trauma patients.

METHODOLOGY & MATERIALS

This prospective, comparative study was conducted over a one-year period from 2022 to 2023 at the Department of Anaesthesia, Analgesia, and Intensive Care Medicine, Bangabandhu Sheikh Mujib Medical University (BSMMU), Dhaka, Bangladesh. The study included 60 patients scheduled for orthopedic trauma surgery, who were randomly assigned to two groups: Group A (UGRA), comprising 30 patients who received ultrasound-guided regional anesthesia, and Group B (Control), comprising 30 patients who received traditional pain management techniques. Inclusion criteria were adults aged 18-75 years undergoing elective or urgent orthopedic trauma surgery, with informed consent obtained from all participants. Exclusion criteria included contraindications to local anesthetics, severe comorbidities, pregnancy, and a history of substance abuse. In Group A, ultrasound-guided regional anesthesia was performed using the Philips Lumify ultrasound device and bupivacaine as the local anesthetic, while Group B received standard pain management based on clinical judgment. Primary outcomes included pain scores at 1, 6, and 24 hours post-surgery and total opioid consumption within the first 24 hours. Secondary outcomes assessed time to first ambulation, length of hospital stay, postoperative complications, and patient satisfaction. Data were analyzed using descriptive and inferential statistics, with significance set at $p < 0.05$. The study was approved by the Institutional Review Board of BSMMU, and written informed consent was obtained from all participants.

RESULTS

Table 1: Demographic Characteristics of the Study Population (N = 60)

Characteristic	Group A (UGRA) (n = 30)	Group B (Control) (n = 30)	p-value
Age (Mean ± SD)	45.3 ± 8.2	46.1 ± 7.9	0.723
Gender (Male/Female) (n)	18/12	19/11	0.804
BMI (Mean ± SD)	27.5 ± 3.4	28.2 ± 3.1	0.502
ASA Classification			
ASA I	8 (26.7%)	10 (33.3%)	0.842
ASA II	16 (53.3%)	15 (50.0%)	0.927
ASA III	6 (20.0%)	5 (16.7%)	1.000

Table 1 summarizes the demographic characteristics of the study participants. Group A (UGRA) and Group B (Control) each consisted of 30 patients. The mean age was 45.3 ± 8.2 years in Group A and 46.1 ± 7.9 years in Group B, with no significant difference (p = 0.723). Gender distribution was similar, with 18 males and 12 females in Group A, and 19 males and 11 females in Group B (p = 0.804). The mean BMI was 27.5 ± 3.4 in Group A and 28.2 ± 3.1 in Group B (p = 0.502). ASA classifications were comparable between the groups, with no significant differences across ASA I, II, and III categories.

Table 2: Intraoperative and Postoperative Outcomes

Outcome	Group A (UGRA)	Group B (Control)	p-value
Duration of Surgery (min)	120.4 ± 15.2	125.1 ± 14.7	0.158
Intraoperative Blood Loss (ml)	300 ± 40	310 ± 45	0.337
Pain Score at 1 Hour (VAS)	2.1 ± 0.9	4.5 ± 1.2	<0.001**
Pain Score at 6 Hours (VAS)	1.8 ± 0.7	4.1 ± 1.1	<0.001**
Pain Score at 24 Hours (VAS)	2.0 ± 0.6	3.8 ± 0.9	<0.001**
Opioid Consumption (mg)	10 ± 5	25 ± 8	<0.001**
Time to First Ambulation (hrs)	24 ± 4	30 ± 5	<0.001**

Table 2 summarizes the intraoperative and postoperative outcomes of Group A (UGRA) and Group B (Control). The duration of surgery was similar between the groups, with Group A averaging 120.4 ± 15.2 minutes and Group B 125.1 ± 14.7 minutes (p = 0.158). Intraoperative blood loss was also comparable, with Group A losing 300 ± 40 ml and Group B 310 ± 45 ml (p = 0.337). However, significant differences were noted in postoperative outcomes. Group A had significantly lower pain scores at 1 hour (2.1 ± 0.9 vs. 4.5 ± 1.2, p < 0.001), 6 hours (1.8 ± 0.7 vs. 4.1 ± 1.1, p < 0.001), and 24 hours post-surgery (2.0 ± 0.6 vs. 3.8 ± 0.9, p < 0.001) compared to Group B, reflecting superior pain control with UGRA. Opioid consumption was markedly lower in Group A (10 ± 5 mg) compared to Group B (25 ± 8 mg), with a p-value of <0.001. Additionally, patients in Group A ambulated earlier, with a time to first ambulation of 24 ± 4 hours compared to 30 ± 5 hours in Group B (p < 0.001). Overall, Group A demonstrated better pain management, reduced opioid use, and faster recovery.

Table 3: Postoperative Complications

Complication	Group A (UGRA)	Group B (Control)	p-value
Nausea/Vomiting	2 (6.7%)	8 (26.7%)	0.034*
Hypotension	3 (10%)	5 (16.7%)	0.456
Respiratory Depression	0 (0%)	3 (10%)	0.077
Nerve Injury	0 (0%)	0 (0%)	N/A
Infection at Injection Site	0 (0%)	0 (0%)	N/A

Table 3 outlines the postoperative complications among the study groups. Group A (UGRA) experienced significantly fewer cases of nausea and vomiting, with only 2 cases (6.7%) compared to 8 cases (26.7%) in Group B (Control), achieving statistical significance (p = 0.034). This highlights the reduced incidence of this complication with UGRA. Hypotension occurred in 10% of Group A and 16.7% of Group B, but this difference was not significant (p = 0.456). Respiratory depression was observed in 10% of Group B but was absent in Group A, though the p-value (0.077) suggests this difference is not statistically significant. Neither group reported any cases of nerve injury or infection at the injection site, rendering these complications non-applicable (N/A) for comparison. These findings suggest UGRA's potential for reducing nausea and vomiting, with other postoperative complications showing no significant differences between groups.

Table 4: Patient Satisfaction and Length of Stay

Parameter	Group A (UGRA)	Group B (Control)	p-value
Patient Satisfaction Score	4.8 ± 0.4	3.5 ± 0.6	<0.001**
Length of Hospital Stay (days)	4 ± 1	6 ± 2	<0.001**

Table 4 highlights the differences in patient satisfaction and length of hospital stay between the two groups. Group A (UGRA) reported significantly higher satisfaction, with an average score of 4.8 ± 0.4 compared to 3.5 ± 0.6 in Group B (Control), a highly significant difference ($p < 0.001$). This indicates that patients in the UGRA group were more satisfied with their pain management experience. Additionally, the UGRA group had a shorter average hospital stay (4 ± 1 days) compared to the control group (6 ± 2 days), again with a statistically significant difference ($p < 0.001$). These findings suggest that UGRA not only enhances patient satisfaction but also reduces the length of hospital stay, indicating more efficient recovery and overall patient management compared to traditional pain control methods.

DISCUSSION

This study evaluated the impact of Ultrasound-Guided Regional Anesthesia (UGRA) on pain management in orthopedic trauma surgery, comparing it with standard pain management practices. The results indicate significant advantages of UGRA in terms of pain control, opioid consumption, postoperative complications, and patient satisfaction. These findings align with recent literature, further supporting the benefits of UGRA in orthopedic procedures.

The study demonstrated that UGRA significantly reduced pain scores at 1, 6, and 24 hours post-surgery compared to the control group. Specifically, pain scores in the UGRA group were 2.1 ± 0.9 at 1 hour, 1.8 ± 0.7 at 6 hours, and 2.0 ± 0.6 at 24 hours, compared to 4.5 ± 1.2, 4.1 ± 1.1, and 3.8 ± 0.9 in the control group, respectively. These results are consistent with recent studies highlighting UGRA's effectiveness in providing superior pain relief. For instance, Rapp *et al.*, (2023) found that UGRA significantly reduced pain scores in the immediate postoperative period (mean pain score of 2.0 ± 1.0 vs. 4.0 ± 1.5 for controls) [25]. Similarly, Wong *et al.*, showed that UGRA provided better postoperative analgesia, with VAS scores of 2.2 ± 0.8 compared to 4.3 ± 1.3 for traditional methods [26]. The precision of UGRA, facilitated by real-time ultrasound imaging, allows for accurate deposition of local anesthetics around nerves, leading to more effective pain relief than traditional methods that rely on anatomical landmarks [27].

The reduction in opioid consumption observed in the UGRA group is a critical finding. Specifically, the UGRA group consumed 10 ± 5 mg of opioids, compared to 25 ± 8 mg in the control group. This underscores UGRA's role in minimizing opioid use, a growing concern due to the opioid epidemic. Khatri *et al.*, reported that UGRA significantly reduced opioid consumption in orthopedic surgery patients, with an average of 12 mg in the UGRA group compared to 30 mg in the control group [28]. Ahmed *et al.*, further supports this, showing that UGRA leads to a substantial decrease in opioid requirements, with 11 ± 4 mg in the UGRA group versus 27 ± 9 mg in the control group [29]. These findings highlight UGRA's potential in mitigating opioid-related risks and side effects.

The study also revealed that patients in the UGRA group ambulated sooner, with a mean time of 24 ± 4 hours, compared to 30 ± 5 hours in the control group. This result aligns with recent research indicating that improved pain management with UGRA facilitates earlier mobilization. Patel *et al.*, demonstrated that UGRA led to earlier mobilization, with a mean time to first ambulation of 23 ± 3 hours compared to 31 ± 6 hours for traditional pain management [30]. This is attributed to UGRA's effectiveness in controlling pain, which promotes faster recovery and mobilization post-surgery. Our findings support the notion that UGRA enhances postoperative recovery by reducing pain and facilitating early ambulation, crucial for preventing complications such as deep vein thrombosis and pulmonary embolism [31].

The study observed a lower incidence of nausea/vomiting (6.7% vs. 26.7%) and respiratory depression (0% vs. 10%) in the UGRA group compared to the control group. These findings are consistent with recent literature indicating that UGRA is associated with fewer adverse effects. Johnson *et al.*, found that UGRA was associated with a lower incidence of postoperative nausea and vomiting (7% vs. 25% with traditional methods) [32]. A review by Lee *et al.*, highlighted that UGRA reduces the risk of respiratory depression, with 0% incidence in the UGRA group compared to 12% in the control group [33]. The reduced incidence of these complications can be attributed to the decreased reliance on systemic opioids and the improved pain management provided by UGRA.

The higher patient satisfaction scores in the UGRA group (4.8 ± 0.4) compared to the control group (3.5 ± 0.6) are consistent with studies showing that UGRA improves overall patient satisfaction. Brown *et al.*, reported higher patient satisfaction scores with UGRA (4.9 ± 0.3) compared to traditional pain management techniques (3.6 ± 0.5) [34]. This improvement in satisfaction can be attributed to more effective pain control and fewer side effects, which enhance the overall patient experience and contribute to better recovery outcomes. The positive impact on patient satisfaction underscores UGRA's potential to improve the quality of care in orthopedic trauma surgery.

The shorter length of hospital stay observed in the UGRA group (4 ± 1 days) compared to the control group (6 ± 2 days) supports the growing body of evidence suggesting that UGRA contributes to faster recovery. Smith *et al.*, found that UGRA was associated with a shorter hospital stay (4.5 ± 1.2 days) compared to traditional pain management (6.5 ± 2.1 days), consistent with our results [35]. The reduced hospital stay can be attributed to improved pain control, earlier ambulation, and fewer complications, which facilitate a quicker discharge and recovery process. This finding highlights UGRA's role in enhancing recovery efficiency and reducing healthcare costs.

Limitations of the study

This study has several limitations that should be considered when interpreting the results. First, the sample size was relatively small, with only 60 patients, which may limit the generalizability of the findings to broader populations. Second, the study was conducted in a single center, potentially introducing site-specific biases related to patient management practices and resources. Additionally, the follow-up period was limited to the immediate postoperative phase, so long-term outcomes such as chronic pain development or functional recovery were not assessed.

Recommendations

Future studies should include a larger, multicenter cohort to improve the generalizability of the findings and capture potential variations in practice patterns. Long-term follow-up is also recommended to assess the sustained impact of UGRA on pain management, functional recovery, and quality of life. Further research should explore the potential benefits of UGRA in reducing opioid dependence, as well as strategies for overcoming the learning curve and improving accessibility to UGRA training. Additionally, cost-effectiveness analyses would be valuable to determine the financial feasibility of widespread UGRA implementation in diverse healthcare settings.

Conclusion

In conclusion, this study's findings align with recent literature supporting UGRA's advantages in pain management for orthopedic trauma surgery. UGRA significantly improves pain control, reduces opioid consumption, minimizes postoperative complications, enhances patient satisfaction, and shortens hospital stay compared to traditional pain management techniques. The precision and safety of UGRA, as facilitated by real-time ultrasound imaging, contribute to these benefits. As the evidence base for UGRA continues to grow, its integration into standard clinical practice for orthopedic trauma surgery appears promising. Further research and increased access to UGRA training and resources could help optimize pain management and improve patient outcomes in orthopedic surgery.

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