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Ultrasound-Guided Regional Anesthesia Versus Conventional Techniques in Reducing Postoperative Pain: A Prospective Randomized Controlled Study.

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Abstract

Background: Post-surgery pain management remains a clinical challenge as far as professionals are concerned. Ultrasound-Guided Regional Anesthesia (UGRA) is guaranteed to be better than landmark-based techniques in theory, but comparative clinical efficacy data remain limited. ***Objective:*** this prospective randomized controlled study was to evaluate the efficacy of ultrasound-guided regional anaesthesia versus the conventional landmark-based techniques in alleviating postoperative pain and reducing opioid consumption. ***Methods:*** This study involved 146 patients allocated in UGRA group and conventional group in random fashion (73 each) undergoing surgical procedures requiring regional anaesthesia. The main outcome of the study was the postoperative pain measured using the Visual Analog Scale (VAS) at 0, 1, 6, 12, and 24 hours. The secondary outcomes assessed were the consumption of opioid, block performance time, sensory block onset time, duration of the analgesia and complications. ***Results:*** The UGRA matrix had mean VAS for 0-24 hours of 2.39 ± 0.82 while the control group had a VAS score of 5.28 ± 1.32 which was statistically significant ($p<0.001$). Opioid consumption was significantly decreased in the UGRA group (12.30 ± 4.83 mg vs. 28.93 ± 7.63 mg morphine equivalent, $p<0.001$, 57.4% decrease). The duration of block performance time was shorter in Group B than Group A (9.01 ± 2.18 vs. 13.24 ± 3.27 minutes, $p<0.001$). Moreover, there was an improvement in the onset time of sensory block in Group B as compared to Group A (7.41 ± 1.84 vs. 12.02 ± 3.30 minutes, $p<0.001$). UGRA group had a significantly prolonged duration of post-operative analgesia as compared to control (10.89 ± 2.12 vs. 7.53 ± 1.67 hours, $p<0.001$). Overall complications in the UGRA group were significantly lower (4.1% vs. 15.1%, $p<0.01$). No vascular puncture and block failure was seen. ***Conclusion:*** ultrasound-guided regional anesthesia is more effective than landmark-based techniques in reducing postoperative pain, opioid consumption, and complications. According to the referenced article, UGRA should be encouraged as the method of choice for perioperative regional anesthesia in patients undergoing surgery who are eligible for it.

Keywords: Ultrasound-guided regional anesthesia;Postoperative pain management;Opioid consumption;Regional anesthesia complications

INTRODUCTION

Postoperative pain management is a challenge but is vital for the recovery, morbidity and satisfaction of patients.[1] An insufficient ability to control pain was responsible for delay in mobilization, thromboembolic complications and prolonged hospital stay[2]. Conventional landmark-based regional anesthesia techniques involve the use of anatomical landmarks and tactile feedback to locate target nerves[3]. Conventional techniques, however, carry risks of vascular puncture, nerve injury, block failure, a 70-95% success rate depending on the procedure and operator experience [4]. Ultrasound-guided regional anaesthesia (UGRA) has been a great advancement in regional anaesthesia over the last two decades [5]. This technique produces dynamic ultrasound images of the target nerve, anatomical structures in the vicinity, and diffusion of local anesthetic, resulting in better needle placement and deposition of local anesthetic[6]. Theoretically, the ability of UGRA to visualize structures is supposed to reduce incidental puncture of blood vessels and nerves, thus improving success rates of blocks and potentially reducing the volume of local anaesthetic required[7].However, although UGRA is theoretically advantageous, there is a paucity of prospective comparative studies in the literature that assess the efficacy of UGRA in reducing post-operative pain as compared to conventional techniques[8]. Further evaluation on whether or not opioid usage, complication rate and block characteristics will be affected in surgical population[9]. The present prospective randomized controlled study aims to evaluate the efficacy of ultrasound-guided regional anaesthesia versus

conventional based on landmark techniques in terms of postoperative pain scores and opioid requirements while assessing the safety profile in a total of 146 surgical patients.

MATERIALS AND METHODS

Study Design and Setting

A prospective randomized controlled study was conducted in the Department of Anaesthesia, Pacific Medical College and Hospital, Udaipur, Rajasthan, India for the period of 1 year (January 2025 to December 2025).

Study Population

Sample Size

In the study, 146 patients were included who were randomly allocated into two groups of equal size.

- **UGRA Group**: Ultrasound-Guided Regional Anesthesia (n=73)
- **Conventional Group**: Conventional Landmark-Based Techniques (n=73)

Inclusion Criteria

Patients were eligible for enrollment if they met all of the following criteria:

- Individuals aged between 18 and 70 years old.
- Patients scheduled to have a procedure requiring regional anesthesia.
- American Society of Anesthesiologists (ASA) has physical condition I-III .
- The participant must be able to provide informed consent in writing to participate in the study.

Exclusion Criteria

- Patients were excluded from the study if they had any of the following conditions:
- Bleeding disorders that is known.
- The needle insertion site must not be infected at the time of needle insertion.
- Neurological disorders affecting the area to be blocked.
- Local anesthetic agents are known allergy.
- A case of pregnancy or lactation.
- Recent chronic use opioid therapy (within the last 3 months).

Randomization and Blinding

Patients were allocated randomly with the help of a computer-generated random number sequence into two groups. To guarantee balanced distribution between procedure categories, randomization was stratified by type of surgery. The allocation sequence was hidden in sealed opaque envelopes, which were opened in a consecutive manner by an independent research coordinator at the time of randomization. The outcome assessor who assessed pain and collected data was blinded to the group allocation during the entire study period.

Anesthetic Techniques

UGRA Group

Anesthesiologists trained in ultrasound-guided techniques performed ultrasound-guided regional anesthesia. For a real-time display of images, a portable ultrasound machine with a high-frequency linear probe (6-13 MHz) was employed. The nerve targeted was identified and visualized both in the short and long axis The needle was advanced using an in-plane technique whereby the needle tip was kept in continuous view along its course until an optimal needle position in relation to the nerve was achieved. A local anesthetic solution containing 0.5% bupivacaine 15-20 mL and 2% lidocaine 10-15 mL was injected under direct ultrasound guidance, with the spread of local anesthetic around the targeted nerve being robustly observed for adequate circumferential spread.

Conventional Group

Landmark based regional anesthesia was performed with anatomy of each block known very well. Utilization of Peripheral nerve stimulator for accurate placement of the needle. Stimulation was set at an intensity of 0.5 mA to get the appropriate motor response in the distribution of the nerve to be targeted. Once the motor response confirmed the correct needle position, the same local anesthetic mixture (0.5% bupivacaine 15-20 mL + 2% lidocaine 10-15 mL) was delivered as per standard clinical practice.

Data Collection

Primary Outcome Measure

- The study's primary outcome was assessed postoperative pain intensity by the visual analog scale (VAS) where 0 is no pain, and 10 is the worst pain (imagined). The outcome assessor, who was blinded, recorded VAS scores at the specified times.
- 0 hours (immediately upon arrival in the recovery room)
- 1 hour postoperatively
- 6 hours postoperatively
- 12 hours postoperatively
- 24 hours postoperatively

Secondary Outcome Measures

Secondary outcomes included the following parameters:

- **Opioid consumption**: Total morphine equivalent dose (in milligrams) administered during the 24-hour postoperative period.
- **Block performance time**: Time interval measured in minutes from skin preparation and disinfection to completion of local anesthetic injection.
- **Time to onset of sensory block**: Time interval in minutes from completion of local anesthetic injection to the patient's first report of sensory change in the blocked distribution.
- **Duration of postoperative analgesia**: Time interval in hours from completion of local anesthetic

injection to the patient's first request for rescue analgesia medication.

- **Rescue analgesia requirements**: Number of additional analgesic doses required during the 24-hour postoperative period.
- **Complications**: Documented occurrence of nerve injury, local anesthetic systemic toxicity (LAST), vascular puncture, hematoma formation, infection at injection site, and pneumothorax.

Statistical Analysis

All statistical analyses were performed using appropriate software. Continuous variables such as age, weight, height, pain scores, opioid consumption, and block performance times were expressed as mean ± standard deviation and were compared between the two groups using the independent samples t-test. Categorical variables including demographic characteristics, gender distribution, ASA status, procedure types, and complication frequencies were analyzed using the chi-square test or Fisher's exact test, as appropriate based on expected cell frequencies. A p-value less than 0.05 was considered statistically significant for all analyses. Ninety-five percent confidence intervals (CI) were calculated for the primary outcome measure where appropriate.

RESULTS

146 patients were enrolled in the study, 73 each in two groups, and the demographics of UGRA group and conventional group were similar. The average age was 42.3 ± 12.8 years in UGRA and 43.1 ± 13.2 years in conventional (p=0.68). There was no gender difference in our study; most patients of UGRA had gender ratio of 61.6% and conventional group had a common gender of 65.8% (p=0.58). The distribution of the ASA status was comparable in both groups; ASA I was encountered in 43.8% of UGRA patients, and 41.1% of conventional patients (p=0.74). In terms of weight (65.4 ± 10.2 kg versus 64.8 ± 9.8 kg, p=0.72) and height (163.2 ± 8.5 cm versus 162.8 ± 8.9 cm, p=0.79), the groups were comparable. Surgical duration also did not differ between groups (78.5 ± 25.3 minutes vs. 80.2 ± 26.1 minutes, p=0.68). Comparison of Surgical Procedures: Upper Limb, Lower Limb Surgery. There was a comparable distribution of surgical procedures. Upper limb cases comprised 38.4% of the UGRA group. And lower limb cases comprised 30.1% of UGRA groups.

Table 1: Demographic and Baseline Characteristics of Study Participants

Characteristic	UGRA Group (n=73)	Conventional Group (n=73)	p-value
Age (years), mean ± SD	42.3 ± 12.8	43.1 ± 13.2	0.68
Male, n (%)	45 (61.6%)	48 (65.8%)	0.58
Female, n (%)	28 (38.4%)	25 (34.2%)	0.58
ASA Status I, n (%)	32 (43.8%)	30 (41.1%)	0.74
ASA Status II, n (%)	35 (47.9%)	37 (50.7%)	0.74
ASA Status III, n (%)	6 (8.2%)	6 (8.2%)	1.00
Weight (kg), mean ± SD	65.4 ± 10.2	64.8 ± 9.8	0.72
Height (cm), mean ± SD	163.2 ± 8.5	162.8 ± 8.9	0.79
Duration of surgery (min), mean ± SD	78.5 ± 25.3	80.2 ± 26.1	0.68

Types of Surgical Procedures:

Procedure Type	UGRA Group (n=73)	Conventional Group (n=73)
Orthopedic (upper limb)	28 (38.4%)	30 (41.1%)
Orthopedic (lower limb)	22 (30.1%)	20 (27.4%)
General surgery	15 (20.5%)	16 (21.9%)
Other procedures	8 (11.0%)	7 (9.6%)

Table 2: Comparison of Postoperative Pain Scores (VAS) Between UGRA and Conventional Groups

Time Point	UGRA Group (n=73)	Conventional Group (n=73)	Mean Difference	p-value
VAS at 0 hours (recovery)	1.42 ± 0.72	3.15 ± 1.08	-1.73	<0.001
VAS at 1 hour	1.93 ± 0.86	4.02 ± 1.42	-2.09	<0.001
VAS at 6 hours	2.41 ± 0.74	5.38 ± 1.50	-2.97	<0.001
VAS at 12 hours	2.64 ± 1.12	5.61 ± 1.46	-2.97	<0.001
VAS at 24 hours	3.58 ± 1.25	6.22 ± 1.51	-2.64	<0.001
Mean VAS (0-24h)	**2.39 ± 0.82**	**5.28 ± 1.32**	**-2.89**	**<0.001**

The UGRA hybrid had significantly lower VAS pain scores than the conventional group at all recorded time points (Table 2). VAS scores at 0 hours (recovery room) were 1.42 ± 0.72 in UGRA and 3.15 ± 1.08 in conventional group (mean differences =-1.73 ,p<0.001). The VAS scores at 1 hr was found to be 1.93 ± 0.86 versus 4.02 ± 1.42 (p<0.001). VAS score at a period of 6 hrs was found to be 2.41 ± 0.74 versus 5.38 ± 1.50 (p<0.001). VAS score at a period of 12 hrs was found to be 2.64 ± 1.12 versus 5.61 ± 1.46 (p<0.001). VAS score at a period of 24 hrs was found to be 3.58 ± 1.25 versus 6.22 ±

1.51 (p<0.001). The mean VAS score throughout the total 24-hour postoperative duration was 2.39 ± 0.82 in the UGRA group and was 5.28 ± 1.32 in the conventional group (mean difference = -2.89, p<0.001) showing a clinically significant reduction in postoperative pain.

Table 3: Comparison of Block Characteristics and Opioid Consumption Between Groups

Parameter	UGRA Group (n=73)	Conventional Group (n=73)	Mean Difference	p-value
Opioid consumption (mg morphine equivalent)	12.30 ± 4.83	28.93 ± 7.63	-16.63	<0.001
Block performance time (minutes)	9.01 ± 2.18	13.24 ± 3.27	-4.23	<0.001
Time to sensory block onset (minutes)	7.41 ± 1.84	12.02 ± 3.30	-4.61	<0.001
Duration of postoperative analgesia (hours)	10.89 ± 2.12	7.53 ± 1.67	+3.36	<0.001
Time to first rescue analgesia (hours)	11.25 ± 2.35	7.82 ± 1.95	+3.43	<0.001
Number of rescue analgesia doses (24h)	1.2 ± 0.8	2.8 ± 1.2	-1.6	<0.001

The block performance time was significantly shorter in UGRA group (9.01 ± 2.18 minutes) than in the conventional group (13.24 ± 3.27 minutes) with mean difference of -4.23 minutes (p<0.001). UGRA group also showed lower time to sensory block onset (7.41 ± 1.84 minutes versus 12.02 ± 3.30 minutes, p<0.001), showing more establishment of neural blockade. The duration of postoperative analgesia was significantly prolonged in the UGRA group (10.89 ± 2.12 hours) compared to the conventional group (7.53 ± 1.67 hours) (mean difference +3.36 hours, p<0.001). As a result, the first requirement for rescue analgesia was significantly delayed in the UGRA group (11.25 ± 2.35 hrs vs. 7.82 ± 1.95 hrs, p<0.001). The UGRA group needed significantly less opioid consumption in the first postoperative 24 hours. The UGRA used an average of 12.30 ± 4.83 mg morphine equivalent as compared to 28.93 ± 7.63 mg in the conventional group (mean difference – 16.63 mg, p<0.001), which is a reduction of 57.4%. The UGRA group required significantly lower doses of rescue analgesia within 24 hours as compared to the GRA group (p<0.001).

Table 4: Comparison of Complications Between UGRA and Conventional Groups

Complication Type	UGRA Group (n=73)	Conventional Group (n=73)	p-value
Total Complications	**3 (4.1%)**	**11 (15.1%)**	**<0.01**
Transient paresthesia	2 (2.7%)	5 (6.8%)	0.32
Vascular puncture	0 (0%)	3 (4.1%)	0.12
Minor hematoma	1 (1.4%)	2 (2.7%)	0.56
Block failure	0 (0%)	1 (1.4%)	0.31
Local anesthetic systemic toxicity	0 (0%)	0 (0%)	-
Permanent nerve injury	0 (0%)	0 (0%)	-
Infection	0 (0%)	0 (0%)	-
Pneumothorax	0 (0%)	0 (0%)	-

Complication Severity:

Severity	UGRA Group	Conventional Group
Minor (resolved within 24h)	3 (100%)	8 (72.7%)
Moderate (resolved within 7 days)	0 (0%)	3 (27.3%)
Severe (persistent >7 days)	0 (0%)	0 (0%)

The UGRA group experienced a significantly lower overall complication rate. Three patients (4.1%). In the UGRA group experienced complications whereas eleven patients (15.1%) in the conventional group (p<0.01). There was a statistically insignificant difference in transient paresthesia between groups (UGRA 2.7% vs conventional 6.8%). There was no occurrence of vascular puncture in the UGRA group. However, three patients (4.1%) had vascular puncture in the conventional group (p=0.12). In both groups, minor hematoma formation occurred rarely (1.4% in UGRA; 2.7% in conventional; p=.56). Block failure was observed in 1 patient (1.4%) of the conventional group but none of the UGRA patients (p=0.31). Notably, neither group experienced any serious complications, including local anesthetic systemic toxicity, permanent nerve injury, infection, or pneumothorax. The entire complication of UGRA group was classified as minor, which resolved within 24 hours and all were minor. Of the complications in the conventional group, 72.7% macropediatric complications were minor and resolved within 24 hours and 27.3%, moderate, resolved within 7 days.

DISCUSSION

The results of this prospective randomized controlled trial indicate that ultrasound-guided regional anesthesia is significantly superior to landmark anesthesia in reducing post-operative pain. The data suggest that the use of UGRA ought to be the standard of care in the perioperative period as VAS pain scores decreased significantly at all the time points.[10] Past studies by Perlas et al.[11] and Marhofer et al.[12] demonstrated the anatomical precision advantage of ultrasound guided techniques; our findings reinforce these benefits in terms of clinical outcomes.

The UGRA group had a significantly prolonged duration of analgesia as compared to the AGRA group (10.89 hours vs. 7.53 hours). This difference is possibly due to better needle positioning and directed local anesthetic distribution around the relevant nerves[13]. This improved block quality leads to delayed pain onset and reduced postoperative requirements of opioid use. The reduced opioid consumption of 57.4% is significant as excessive opioid use can cause respiratory depression, gastrointestinal system complications, prolonged recovery, etc., in patients and can contribute to opioid-related AEs[14]. Our results corroborate recent meta-analyses by Hebl et al.16 that showed reduced demand for opioids when ultrasound-guided techniques were used in various surgical populations.The enhanced safety profile of UGRA, shown by a four times less overall complication rate (4.1% vs. 15.1%), supports the prior findings regarding the reduced nerve and vascular injuries with confirmation[16]. The UGRA group had no vascular puncture whereas 3 (4.1%) of the cases had vascular puncture in the conventional group. The direct visualization helped in avoiding the vascular puncture. Furthermore, the complete resolution of UGRA-related complications within a time frame of 24 hours, in comparison to 27.3% who required up to 7 days in the conventional group, suggests these complications, when they occur, are less severe, in general[17].According to [13], faster block performance time (9.01 vs. 13.24 minutes) in the UGRA group may be due to better anatomical knowledge and more efficient needle placement, resulting in fewer redirections of the needle or extra block attempts. This efficiency has important implications for the operating room workflows and patient preparation time. Nevertheless, there are some limitations. The predominance of patients in both groups undergoing orthopedic intervention (68.5%) may limit the generalizability of the findings to other surgical specialties. The experience of the operator with ultrasound guidance was not specified, and results may vary according to learning curves in less experienced practitioners[18]. In addition, they did not study the costs of UGRA, including those for equipment and training of personnel, which are important for health systems[19].The results of the study strongly recommend the use of ultrasound-guided regional anesthesia technique for perioperative anesthesia in eligible surgical patients. The use of ultrasonographically-guided regional anaesthesia (UGRA) can control pain in the perioperative phase. Moreover, it can reduce opioid requirements and the enhanced safety profile. The action serves as an important adjunct of multimodal perioperative pain management strategies.

CONCLUSION

This randomized control trial provides evidence that ultrasound-guided regional anaesthesia is superior to landmark-based techniques in decreasing postoperative pain and lowering opioid requirements by 57.4% and complication rates associated with the procedure. The better safety profile, quicker onset of the block and longer duration of analgesia of UGRA justify its recommendation as the standard-of-care technique for perioperative regional anaesthesia. According to these findings, a thorough understanding of ultrasound guidance and its clinical usage will change the outcome in a better way.

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