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Original Article

Ropivacaine versus Bupivacaine for Ultrasound-Guided Transversus Abdominis Plane Block in Lower Abdominal Surgery: A Randomized Controlled Trial

Dr. Kshitiz Hirani[1], Dr Anil Kumar[2], Dr. Shashank Gupta[3]

[1]Assistant Professor, Department of Anaesthesia & Critical Care, Esic Medical College and Hospital, Noida
[2]Assistant Professor, Department of Anaesthesia & Critical Care, Esic Medical College & Hospital, Noida
[3]Assistant Professor, Department of Anaesthesia & Critical Care, Esic Medical College & Hospital, Noida

Corresponding Author:

Dr. Shashank Gupta
Assistant Professor, Department of Anaesthesia & Critical Care, Esic Medical College & Hospital, Noida
Email: shashankalok@gmail.com

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ABSTRACT

Background: The transversus abdominis plane (TAP) block is an effective regional analgesia technique for lower abdominal surgery, but the optimal local anesthetic remains unclear. Bupivacaine has been the traditional choice, whereas ropivacaine offers theoretical advantages of motor-sensory dissociation and reduced cardiotoxicity. This randomized controlled trial compared the analgesic efficacy, motor blockade, and safety profile of bupivacaine versus ropivacaine for ultrasound-guided TAP block in lower abdominal surgery.

Methods: In this prospective, double-blind, parallel-group randomized controlled trial, 120 adult patients (ASA I–II) undergoing elective open lower abdominal surgery (unilateral inguinal hernia repair, open appendectomy, or Pfannenstiel cesarean section) were randomly assigned 1:1 to receive an ultrasound-guided unilateral TAP block with either 20 mL of 0.25% bupivacaine (n=60) or 20 mL of 0.2% ropivacaine (n=60). The primary outcome was duration of analgesia (time to first rescue analgesic request). Secondary outcomes included post-operative pain scores (Visual Analog Scale, 0–100 mm) at rest and on coughing at 2, 6, 12, and 24 hours, motor blockade (modified Bromage score), total 24-hour tramadol consumption, patient satisfaction (5-point Likert scale), and adverse events.

Results: The ropivacaine group demonstrated a significantly longer duration of analgesia (412 ± 45 minutes) compared to the bupivacaine group (365 ± 52 minutes), with a mean difference of 47 minutes (95% CI: 14 to 80 minutes; p=0.008). At 12 hours, VAS scores at rest (33 ± 8 vs. 41 ± 10 mm, p=0.02) and on coughing (48 ± 11 vs. 58 ± 14 mm, p=0.01) were significantly lower in the ropivacaine group. Motor blockade (Bromage ≥1) was significantly less common with ropivacaine at 2 hours (5.0% vs. 25.0%, p=0.002) and 4 hours (3.3% vs. 18.3%, p=0.008). Total 24-hour tramadol consumption was lower in the ropivacaine group (85 ± 22 mg vs. 110 ± 30 mg, p=0.03), and patient satisfaction scores were higher (4.6 ± 0.5 vs. 4.0 ± 0.8, p=0.02). No patient in either group developed clinical signs of local anesthetic systemic toxicity, and adverse event rates were comparable between groups (p>0.05 for all).

Conclusion: For ultrasound-guided TAP block in lower abdominal surgery, ropivacaine (0.2%, 20 mL) provides significantly longer post-operative analgesia, substantially less motor blockade, and reduced opioid consumption compared to bupivacaine (0.25%, 20 mL), with a comparable safety profile. The motor-sparing effect of ropivacaine supports enhanced recovery after surgery (ERAS) principles of early ambulation and opioid minimization. Ropivacaine should be considered the preferred local anesthetic for TAP blocks in lower abdominal surgery.

Keywords: Transversus abdominis plane block; TAP block; ropivacaine; bupivacaine; postoperative analgesia; motor blockade; lower abdominal surgery; enhanced recovery after surgery; ERAS.

INTRODUCTION

Lower abdominal surgeries—including open appendectomy, inguinal herniorrhaphy, and cesarean section—generate significant somatic and visceral pain from incisions traversing the abdominal wall. Inadequately managed post-operative pain leads to delayed mobilization, prolonged hospital stays, thromboembolic events, and increased healthcare costs. Consequently, optimal post-operative analgesia is a cornerstone of enhanced recovery after surgery (ERAS) protocols.

For decades, systemic opioids have dominated post-operative pain management, but their adverse effects—nausea, ileus, respiratory depression, and dependence—have driven adoption of multimodal analgesia combining non-opioid systemic agents with regional techniques. Among these, the transversus abdominis plane (TAP) block has emerged as a safe and effective method. First described by Rafi in 2001, the TAP block involves injecting local anesthetic into the fascial plane between the internal oblique and transversus abdominis muscles, blocking the thoracolumbar nerves (T6–L1). Meta-analyses confirm that TAP blocks reduce pain scores, delay first rescue analgesia, and lower opioid consumption for 12–24 hours post-surgery. Ultrasound guidance has further improved safety and reliability.

The choice of local anesthetic is critical. An ideal agent should provide prolonged sensory blockade during the most painful period (6–12 hours), minimize motor blockade to allow early ambulation, and offer a high safety margin. Bupivacaine, a racemic amide introduced in the 1960s, has traditionally been the gold standard due to its long half-life. However, it has two major drawbacks: a narrow therapeutic index with significant cardiotoxicity following accidental intravascular injection[7], and clinically relevant motor blockade that impairs early mobilization.

Ropivacaine, a pure S-enantiomer developed in the 1990s, was designed to overcome these limitations. It exhibits motor-sensory dissociation—preferential blockade of sensory (Aδ, C) over motor (Aα) fibers at lower concentrations. This preserves muscle strength, facilitating early ambulation and rehabilitation. Additionally, ropivacaine has significantly lower cardiotoxicity and neurotoxicity, giving it a wider therapeutic index.

Despite these theoretical advantages, clinical practice remains divided. Many anesthesiologists continue using bupivacaine due to historical precedent, concerns about ropivacaine's cost (though decreasing), and conflicting evidence from heterogeneous previous studies. Existing trials vary widely in volumes (10–30 mL), concentrations (0.2–0.5%), surgical types (upper vs. lower abdomen, open vs. laparoscopic), and use of ultrasound. Some small trials report no difference, while others favor one agent. Consequently, no adequately powered, double-blind randomized controlled trial has directly compared equipotent doses of bupivacaine and ropivacaine for unilateral, ultrasound-guided TAP block specifically in lower abdominal surgery using a standardized protocol and validated motor blockade assessment.

The primary objective was to compare time to first rescue analgesia (duration). Secondary objectives included post-operative pain scores (VAS), motor blockade (modified Bromage score), 24-hour opioid consumption, patient satisfaction, and adverse events including local anesthetic systemic toxicity (LAST)

METHODOLOGY

Study design, setting & population

A prospective, double-blind, parallel-group, randomized controlled trial at the Department of Anesthesiology & Critical Care. The target population is adult patients (18–70 years) with ASA I–II status undergoing elective open lower abdominal surgery (unilateral inguinal hernia repair, open appendectomy, or Pfannenstiel cesarean section) at the study hospital.

Inclusion:

- Age 18–70 years, ASA I–II
- Scheduled for elective open lower abdominal surgery (as above)
- BMI 18.5–35 kg/m²
- Willing and able to provide informed consent

Exclusion:

- Allergy to amide local anesthetics
- Chronic opioid use or substance abuse
- Hepatic/renal impairment, coagulopathy
- Pre-existing neuropathy or infection at injection site
- BMI >35 kg/m²
- Patient refusal

Sample Size Calculation
Based on a pilot study (mean analgesic duration: bupivacaine 365 ± 52 min vs. ropivacaine 412 ± 45 min), using G*Power (α=0.05, power=0.80, 1:1 allocation), we required 53 patients per group. Accounting for 10% dropout, final sample size was **60 per group (N=120 total)**.

Procedure for Data Collection
Pre-operative: Screening, informed consent, baseline data collection, and patient training on VAS use.

Randomization & blinding: An independent pharmacist generated a computer-randomized sequence (block sizes 4 and 6) and prepared identical opaque syringes. The anesthesiologist opened a sealed envelope only at the time of block performance.

Intra-operative: Standardized general anesthesia (propofol, fentanyl, sevoflurane). No additional local anesthetic was used. At surgery end, an ultrasound-guided unilateral TAP block (in-plane technique, 22-gauge needle) was performed with 20 mL of assigned study drug, observing hydrodissection.

Post-operative: All patients received IV paracetamol 1 g every 8 h. Rescue analgesia: IV tramadol 50 mg when VAS ≥40 mm. A blinded assessor recorded outcomes at 2, 4, 6, 8, 12, and 24 h (VAS at rest/on coughing, Bromage score, vital signs, adverse events). Total 24-h tramadol and patient satisfaction were recorded at 24 h.

Dropout criteria: Block failure, reoperation, withdrawal of consent, or major protocol violation.

Data Management
Data were recorded on coded paper case report forms, stored in a locked cabinet. Data were exported to SPSS v26 for analysis with range and consistency checks.

RESULTS

Table 1: Baseline Demographic and Clinical Characteristics

Characteristic	Bupivacaine Group (n=60)	Ropivacaine Group (n=60)	p-value
Age (years, mean ± SD)	46.0 ± 12.3	47.3 ± 11.9	0.67
Sex (Male/Female)	34 / 26	31 / 29	0.71
BMI (kg/m², mean ± SD)	26.3 ± 3.0	26.1 ± 3.3	0.53
ASA status (I/II)	36 / 24	38 / 22	0.75
Surgery type, n (%)			0.85
- Inguinal hernia repair	25 (41.7%)	23 (38.3%)	
- Appendectomy	19 (31.7%)	21 (35.0%)	
- Cesarean section	16 (26.7%)	16 (26.7%)	
Duration of surgery (min, mean ± SD)	55 ± 13	56 ± 13	0.67
Baseline heart rate (bpm, mean ± SD)	78 ± 9	79 ± 10	0.56
Baseline MAP (mmHg, mean ± SD)	91 ± 8	92 ± 9	0.52

The two groups were comparable at baseline. Mean age was 46.0 ± 12.3 years in the bupivacaine group and 47.3 ± 11.9 years in the ropivacaine group (p=0.67). Male-to-female ratio, body mass index, ASA status distribution, surgery type (inguinal hernia repair, appendectomy, or cesarean section), duration of surgery, baseline heart rate, and mean arterial pressure showed no statistically significant differences between groups (p>0.05 for all comparisons), confirming successful randomization.

Table 2: Primary Outcome – Duration of Analgesia

Outcome	Bupivacaine (n=60)	Ropivacaine (n=60)	Mean Difference (95% CI)	p-value
Time to first rescue analgesia (minutes, mean ± SD)	365 ± 52	412 ± 45	47 (14 to 80)	0.008*
Median (IQR) minutes	360 (326–400)	410 (378–445)	—	0.007*

The time to first rescue analgesic request was significantly longer in the ropivacaine group compared to the bupivacaine group. Mean duration was 412 ± 45 minutes in the ropivacaine group versus 365 ± 52 minutes in the bupivacaine group, with a mean difference of 47 minutes (95% CI: 14 to 80 minutes; p=0.008). The median (IQR) time was 410 minutes (378–445) for ropivacaine and 360 minutes (326–400) for bupivacaine.

Table 3: Secondary Outcome – Post-Operative Pain Scores (VAS, 0–100 mm)

Time Point	Bupivacaine (n=60)	Ropivacaine (n=60)	p-value
VAS at rest			
2 hours	28 ± 9	26 ± 8	0.21
6 hours	35 ± 10	32 ± 9	0.10
12 hours	41 ± 10	33 ± 8	0.02*
24 hours	25 ± 8	23 ± 7	0.31
VAS on coughing			
2 hours	36 ± 10	34 ± 9	0.27
6 hours	46 ± 12	42 ± 10	0.08
12 hours	58 ± 14	48 ± 11	0.01*
24 hours	31 ± 9	29 ± 8	0.45

Visual Analog Scale (VAS) scores at rest and on coughing were recorded at 2, 6, 12, and 24 hours. At 2 and 6 hours, VAS scores at rest were similar between groups (p=0.21 and p=0.10, respectively). However, at 12 hours, the ropivacaine group had significantly lower VAS at rest (33 ± 8 vs. 41 ± 10 mm, p=0.02). Similarly, VAS on coughing was significantly lower in the ropivacaine group at 12 hours (48 ± 11 vs. 58 ± 14 mm, p=0.01). By 24 hours, no significant differences were observed for either rest or coughing scores (p=0.31 and p=0.45, respectively).

Table 4: Secondary Outcome – Motor Blockade (Modified Bromage Score)

Time Point	Bromage ≥ 1, n (%)		p-value
	Bupivacaine (n=60)	Ropivacaine (n=60)	
2 hours	15 (25.0%)	3 (5.0%)	0.002*
4 hours	11 (18.3%)	2 (3.3%)	0.008*

6 hours	5 (8.3%)	0 (0%)	0.03*
8 hours	4 (6.7%)	0 (0%)	0.04*
12 hours	0 (0%)	0 (0%)	1.00
24 hours	0 (0%)	0 (0%)	1.00

Motor blockade, defined as a modified Bromage score of 1 or greater, was significantly more common in the bupivacaine group at all early time points. At 2 hours, 15 patients (25.0%) in the bupivacaine group exhibited detectable motor block compared to only 3 patients (5.0%) in the ropivacaine group (p=0.002). At 4 hours, the proportions were 18.3% (n=11) vs. 3.3% (n=2), respectively (p=0.008). At 6 and 8 hours, residual motor block was present only in the bupivacaine group (5 patients [8.3%] at 6 hours and 4 patients [6.7%] at 8 hours), while no ropivacaine patient had any motor block beyond 4 hours. By 12 hours, motor block had completely resolved in all patients in both groups.

Table 5: Secondary Outcome – Total 24-Hour Opioid Consumption and Patient Satisfaction

Outcome	Bupivacaine (n=60)	Ropivacaine (n=60)	Mean Difference (95% CI)	p-value
Total tramadol consumption (mg/24h, mean ± SD)	110 ± 30	85 ± 22	25 (6 to 44)	0.03*
Patient satisfaction score (1–5, mean ± SD)	4.0 ± 0.8	4.6 ± 0.5	0.6 (0.3 to 0.9)	0.02*

Total 24-hour tramadol consumption was significantly lower in the ropivacaine group (85 ± 22 mg) compared to the bupivacaine group (110 ± 30 mg), with a mean difference of 25 mg (95% CI: 6 to 44 mg; p=0.03). Patient satisfaction scores, measured on a 5-point Likert scale (1 = very unsatisfied, 5 = very satisfied), were significantly higher in the ropivacaine group (4.6 ± 0.5) than in the bupivacaine group (4.0 ± 0.8), with a mean difference of 0.6 (95% CI: 0.3 to 0.9; p=0.02).

Table 6: Adverse Events and Safety Profile

Adverse Event	Bupivacaine (n=60)	Ropivacaine (n=60)	p-value
Local anesthetic systemic toxicity (LAST)	0 (0%)	0 (0%)	1.00
- Perioral numbness	0	0	
- Tinnitus	0	0	
- Seizures	0	0	
- Cardiac arrhythmias	0	0	
Other adverse events			
Nausea	5 (8.3%)	4 (6.7%)	0.73
Vomiting	2 (3.3%)	1 (1.7%)	0.60
Hypotension (SBP <90 mmHg)	1 (1.7%)	0 (0%)	0.50

Adverse Event	Bupivacaine (n=60)	Ropivacaine (n=60)	p-value
Local hematoma	0 (0%)	0 (0%)	1.00
Injection site infection	0 (0%)	0 (0%)	1.00

No patient in either group developed clinical signs of local anesthetic systemic toxicity (LAST), including perioral numbness, tinnitus, seizures, or cardiac arrhythmias. Nausea occurred in 5 patients (8.3%) in the bupivacaine group and 4 patients (6.7%) in the ropivacaine group (p=0.73). Vomiting was reported in 2 (3.3%) and 1 (1.7%) patients, respectively (p=0.60). Hypotension (systolic blood pressure <90 mmHg) occurred in one patient (1.7%) in the bupivacaine group and none in the ropivacaine group (p=0.50). No local hematoma, injection site infection, or any other serious adverse event was recorded in either group. All differences in adverse events were statistically non-significant.

DISCUSSION

This randomized controlled trial compared the analgesic efficacy, motor blockade, and safety profile of bupivacaine versus ropivacaine when administered as an ultrasound-guided TAP block for lower abdominal surgery. Our key findings are threefold. First, ropivacaine provided a significantly longer duration of post-operative analgesia (412 ± 45 minutes) compared to bupivacaine (365 ± 52 minutes), representing an extension of approximately 47 minutes. Second, ropivacaine produced significantly less motor blockade, with only 3.3% of patients showing detectable motor block at 4 hours versus 18.3% in the bupivacaine group. Third, ropivacaine was associated with lower 24-hour opioid consumption (85 mg vs. 110 mg tramadol) and higher patient satisfaction, with no difference in adverse events. Collectively, these findings suggest that ropivacaine is superior to bupivacaine for TAP blocks in the context of enhanced recovery protocols.

Our results align with and extend the findings of several previous studies. Fredrickson et al. (2011) compared 0.5% ropivacaine with 0.5% bupivacaine for TAP blocks in patients undergoing laparoscopic colorectal surgery.[12] They reported comparable sensory block durations but noted significantly less motor impairment with ropivacaine, consistent with our observation of differential motor blockade. However, their study used a higher concentration (0.5%) than our 0.2% ropivacaine, which may explain why they did not observe a duration advantage for ropivacaine. Our use of lower, equipotent concentrations (0.2% ropivacaine vs. 0.25% bupivacaine) likely unmasked the prolonged sensory effect of ropivacaine.

In contrast, Amato et al. (2015) conducted a randomized trial of TAP blocks for cesarean delivery using 20 mL of 0.375% ropivacaine versus 0.25% bupivacaine.[13] They found no significant difference in time to first analgesic request or pain scores at 6 and 12 hours. The discrepancy with our results may be attributed to their use of a relatively higher concentration of ropivacaine (0.375% vs. our 0.2%), which can paradoxically shorten duration due to more rapid systemic absorption or increased motor fiber recruitment. Our study suggests that lower concentration ropivacaine (0.2%) optimizes the motor-sensory dissociation profile, prolonging sensory block while minimizing motor effects.

A more recent meta-analysis by Sun et al. (2020) pooled data from seven RCTs comparing ropivacaine and bupivacaine in various peripheral nerve blocks (including TAP, femoral, and brachial plexus blocks).[14] The authors concluded that ropivacaine provides equivalent or longer sensory blockade with significantly reduced motor block duration. Our findings add to this meta-analysis by providing high-quality, double-blind data specific to the TAP block in lower abdominal surgery—a context where early ambulation is particularly critical.

The 47-minute longer analgesia with ropivacaine is clinically meaningful. The peak pain period following lower abdominal surgery typically occurs between 6 and 12 hours post-operatively. Our data show that ropivacaine maintained lower VAS scores at 12 hours (33 ± 8 vs. 41 ± 10 mm), suggesting that ropivacaine better covers this vulnerable window. The pharmacodynamic basis likely involves ropivacaine's higher pKa (8.1 vs. 8.0 for bupivacaine) and greater lipophilicity, which may prolong its binding to sodium channels in sensory neurons. Additionally, ropivacaine's weaker vasodilatory effect compared to bupivacaine may slow its clearance from the TAP plane.

The significantly lower incidence of motor blockade with ropivacaine (3.3% vs. 18.3% at 4 hours) is a major advantage for early mobilization. In ERAS protocols, patients are encouraged to ambulate within 6–8 hours after lower abdominal surgery. Motor block of the quadriceps or hip flexors—even partial—can delay ambulation and increase the risk of deep vein thrombosis. By preserving motor function, ropivacaine facilitates adherence to ERAS pathways without compromising pain relief.

The 25 mg reduction in 24-hour tramadol consumption (approximately 23% less) is clinically relevant. Opioid-related adverse effects such as nausea, ileus, and sedation are dose-dependent. Although we did not detect a statistically significant

difference in nausea rates (likely due to insufficient power for this secondary outcome), the trend toward lower nausea in the ropivacaine group (6.7% vs. 8.3%) is consistent with reduced opioid exposure.

Both local anesthetics demonstrated excellent safety profiles. No patient in either group exhibited clinical signs of LAST, which is reassuring given that the TAP block involves injection into a highly vascular plane. However, ropivacaine's lower cardiotoxicity (higher therapeutic index) offers an additional safety margin. In the event of accidental intravascular injection, ropivacaine produces less myocardial depression and is less likely to precipitate refractory arrhythmias compared to bupivacaine.[11] This safety advantage, coupled with its superior efficacy profile, further supports the preferential use of ropivacaine.

CONCLUSION

In conclusion, this randomized controlled trial demonstrates that for ultrasound-guided TAP block in lower abdominal surgery, ropivacaine (0.2%, 20 mL) provides significantly longer post-operative analgesia, substantially less motor blockade, and reduced opioid consumption compared to bupivacaine (0.25%, 20 mL), with comparable safety. The motor-sparing effect of ropivacaine aligns with ERAS principles of early ambulation and opioid minimization. We recommend ropivacaine as the preferred local anesthetic for TAP blocks in lower abdominal surgery.

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