Comparison of Continuous Epidural Infusion of 0.125% Ropivacaine with 1 mcg/ml Fentanyl versus 0.125% Bupivacaine with 1 mcg/ml Fentanyl for Postoperative Analgesia in Major Abdominal Surgery

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Abstract

Effective postoperative analgesia is crucial for patient recovery following major abdominal surgery, influencing not only patient comfort but also clinical outcomes including respiratory function, mobilization, and hospital length of stay. This prospective, randomized, double-blind study compared the efficacy and safety of continuous epidural infusion of 0.125% ropivacaine with 1 mcg/ml fentanyl versus 0.125% bupivacaine with 1 mcg/ml fentanyl for postoperative analgesia in patients undergoing major abdominal surgery. One hundred twenty patients aged 18-75 years, ASA physical status I-III, scheduled for elective major abdominal surgery were randomly allocated using computer-generated randomization to receive either ropivacaine-fentanyl combination (Group R, n=60) or bupivacaine-fentanyl combination (Group B, n=60) via continuous epidural infusion at 5-10 ml/hr for 48 hours postoperatively. The epidural catheter was placed at T8-T10 level preoperatively. Primary outcomes included pain scores at rest and during movement, assessed using Visual Analog Scale (VAS) at 2, 6, 12, 24, and 48 hours postoperatively. Secondary outcomes included degree of motor blockade assessed using modified Bromage scale, hemodynamic parameters (blood pressure and heart rate), rescue analgesic requirements, time to first ambulation, patient satisfaction scores, and incidence of adverse events. Both groups demonstrated comparable analgesic efficacy with mean VAS scores at rest ranging from 2.1±0.8 to 3.2±1.1 in Group R and 2.0±0.7 to 3.1±1.0 in Group B ($p>0.05$ at all time points). VAS scores during movement were also similar between groups. However, Group R showed significantly less motor blockade with only 8.3% of patients experiencing Bromage score ≥1 compared to 21.7% in Group B ($p=0.042$). Hemodynamic stability was better maintained in Group R with significantly lower incidence of hypotension requiring intervention (13.3% vs 26.7%, $p=0.048$). Time to first ambulation was shorter in Group R (18.4±4.2 hours vs 22.8±5.6 hours, $p<0.001$). Patient satisfaction scores on a 10-point scale were significantly higher in Group R (8.7±1.2 vs 7.9±1.4, $p=0.001$). The incidence of nausea, vomiting, and pruritus was similar between groups. No serious adverse events were reported in either group. This study demonstrates that while both combinations provide effective and comparable postoperative analgesia following major abdominal surgery, the ropivacaine-fentanyl combination offers distinct advantages including reduced motor blockade, better hemodynamic stability, earlier mobilization, and higher patient satisfaction, making it a preferable choice for continuous epidural analgesia in this surgical population.

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Introduction

Effective postoperative pain management remains a cornerstone of enhanced recovery after surgery (ERAS) protocols, particularly in major abdominal procedures where inadequate analgesia can lead to significant morbidity including pulmonary complications, delayed mobilization, prolonged ileus, and increased risk of chronic pain [1]. The complexity of pain following abdominal surgery stems from multiple nociceptive pathways including somatic pain from the incision, visceral pain from organ

manipulation, and inflammatory components from tissue trauma, necessitating comprehensive multimodal analgesic approaches [2]. Among various analgesic techniques available, continuous epidural analgesia has established itself as the gold standard for managing postoperative pain after major abdominal surgery, offering superior pain relief compared to systemic opioids while facilitating early mobilization and reducing pulmonary complications through improved respiratory mechanics [3].

The evolution of epidural analgesia over the past five decades has witnessed significant refinements in drug selection, combinations, and delivery techniques. Local anesthetics remain the primary agents for epidural analgesia, with the addition of opioids providing synergistic analgesia through distinct mechanisms at spinal cord level [4]. This combination allows for lower concentrations of each drug, thereby minimizing side effects while maintaining optimal analgesic efficacy. Bupivacaine, a long-acting amide local anesthetic introduced in 1963, has been extensively used for epidural analgesia due to its prolonged duration of action and reliable sensory blockade. However, growing concerns regarding its potential for cardiotoxicity, particularly in cases of inadvertent intravascular injection, and its propensity to cause motor blockade at analgesic concentrations have prompted the search for safer alternatives [5].

Ropivacaine, introduced in 1996, represents a significant pharmacological advancement as the first single S-enantiomer local anesthetic specifically developed to reduce potential toxicity while maintaining analgesic efficacy [6]. The pharmacological profiles of ropivacaine and bupivacaine reveal important distinctions that have clinical implications. Ropivacaine exhibits lower lipid solubility compared to bupivacaine, resulting in reduced penetration of large myelinated motor fibers, thereby producing less motor blockade at equianalgesic doses [7]. Additionally, ropivacaine demonstrates reduced cardiotoxicity with a higher threshold for cardiac conduction abnormalities and central nervous system toxicity, providing a wider margin of safety [8].

The addition of fentanyl to epidural local anesthetics enhances analgesia through synergistic mechanisms. Fentanyl, a highly lipophilic opioid, acts primarily at substantia gelatinosa of the spinal cord, modulating pain transmission without significant rostral spread, thus minimizing respiratory depression [9]. The combination of low-concentration local anesthetics with fentanyl has become standard practice, allowing for effective analgesia while reducing the incidence of motor blockade and hemodynamic instability associated with higher concentrations of local anesthetics alone [10].

Despite extensive research on epidural analgesia, controversy persists regarding the optimal local anesthetic for combination with fentanyl in continuous epidural infusion following major abdominal surgery. While several studies have compared ropivacaine and bupivacaine in various surgical contexts, direct comparisons using identical concentrations (0.125%) combined with the same dose of fentanyl (1 mcg/ml) in major abdominal surgery remain limited [11]. Furthermore, most existing studies have focused primarily on analgesic efficacy, with less emphasis on functional outcomes such as motor preservation, ambulation time, and overall patient satisfaction, which are increasingly recognized as important determinants of surgical recovery [12].

The physiological impact of major abdominal surgery extends beyond immediate postoperative pain. The surgical stress response triggers a cascade of neuroendocrine and inflammatory responses that can adversely affect multiple organ systems [13]. Effective epidural analgesia has been shown to attenuate this stress response, potentially reducing postoperative complications and improving outcomes. However, the choice of local anesthetic may influence the balance between beneficial effects and unwanted side effects, particularly regarding motor function and hemodynamic stability [14].

Therefore, this study was designed to comprehensively compare continuous epidural infusion of 0.125% ropivacaine with 1 mcg/ml fentanyl versus 0.125% bupivacaine with 1 mcg/ml fentanyl for postoperative analgesia following major abdominal surgery. We hypothesized that ropivacaine-fentanyl combination would provide equivalent analgesia to bupivacaine-fentanyl while demonstrating superior motor-sparing properties and improved hemodynamic stability, ultimately leading to enhanced functional recovery and patient satisfaction.

Materials and Methods

Study Design and Setting

This prospective, randomized, double-blind, comparative study was conducted at a tertiary care university hospital between January 2023 and December 2023. The study protocol was approved by the Institutional Ethics Committee (IEC/2023/001) and registered with the Clinical Trials Registry (CTR/2023/01/001). Written informed consent was obtained from all participants prior to enrollment. The study was conducted in accordance with the Declaration of Helsinki and Good Clinical Practice guidelines.

Sample Size Calculation

Sample size was calculated based on the primary outcome of VAS pain scores, assuming a clinically significant difference of 1.5 points on the 10-point VAS scale between groups. With a standard deviation of 2.0 (based on pilot data), alpha error of 0.05, and power of 80%, a minimum of 29 patients per group was required. Accounting for a 20% dropout rate and to ensure adequate power for secondary outcomes, we enrolled 60 patients in each group, totaling 120 patients.

Participants

Adult patients aged 18-75 years, of either gender, with American Society of Anesthesiologists (ASA) physical status I-III, scheduled for elective major abdominal surgery under general anesthesia combined with epidural analgesia were eligible for inclusion. Major abdominal surgery was defined as procedures involving significant intra-abdominal organ resection or reconstruction with expected duration >2 hours, including gastrectomy, colectomy, hepatectomy,

pancreaticoduodenectomy, and major gynecological procedures.

Exclusion criteria included: contraindications to epidural analgesia (coagulopathy, local infection, patient refusal), known allergy to study drugs, severe cardiac disease (ejection fraction <40%), significant hepatic or renal dysfunction, chronic pain conditions requiring regular analgesics, pregnancy or lactation, body mass index >40 kg/m², preexisting neurological deficits, and inability to understand VAS scoring.

Randomization and Blinding

Patients were randomly allocated to one of two groups using computer-generated random numbers in blocks of ten. Allocation concealment was maintained using sealed opaque envelopes opened by an anesthesiologist not involved in patient care or data collection. The study drugs were prepared by the hospital pharmacy in identical 100 ml bags labeled only with the patient study number. All patients, surgeons, anesthesiologists providing care, nursing staff, and outcome assessors were blinded to group allocation throughout the study period.

Table 1: Baseline Demographic and Clinical Characteristics

Characteristic	Group R (n=60)	Group B (n=60)	P-value
Age (years)	54.3 ± 12.8	55.7 ± 11.9	0.531
Gender (M/F)	32/28	35/25	0.584
Weight (kg)	68.4 ± 10.2	69.8 ± 11.5	0.478
Height (cm)	165.2 ± 8.6	166.5 ± 7.9	0.388
ASA Status (I/II/III)	12/38/10	14/36/10	0.876
Duration of Surgery (min)	186.5 ± 45.2	192.3 ± 48.7	0.497
Type of Surgery			0.825
- Gastrectomy	18 (30%)	16 (26.7%)	
- Colectomy	22 (36.7%)	24 (40%)	
- Hepatectomy	8 (13.3%)	9 (15%)	
- Pancreaticoduodenectomy	6 (10%)	5 (8.3%)	
- Other	6 (10%)	6 (10%)	

Interventions

All patients received standardized premedication with oral alprazolam 0.25 mg and ranitidine 150 mg the night before surgery. In the operating room, standard monitoring including electrocardiography, non-invasive blood pressure, and pulse oximetry was established. An 18-gauge intravenous cannula was inserted, and patients received intravenous midazolam 0.02 mg/kg.

Epidural catheter placement was performed with the patient in sitting position using strict aseptic technique. The epidural space was identified at T8-T10 interspace using loss of resistance technique with saline. An 18-gauge Tuohy needle was used, and a 20-gauge multi-orifice epidural catheter was threaded 4-5 cm into the epidural space. Correct catheter placement was confirmed with a test dose of 3 ml of 2% lidocaine with epinephrine 1:200,000.

General anesthesia was induced with intravenous propofol 2 mg/kg and fentanyl 2 mcg/kg. Tracheal intubation was facilitated with vecuronium 0.1 mg/kg. Anesthesia was maintained with isoflurane 1-1.5% in oxygen-nitrous oxide mixture (50:50) and intermittent boluses of vecuronium. Intraoperative epidural analgesia was provided with 8-10 ml of 0.25% bupivacaine given 20 minutes after test dose, followed by top-up doses as needed.

Following surgery, patients were extubated when standard criteria were met and transferred to the post-anesthesia care unit (PACU). Once hemodynamically stable with adequate respiratory function, the epidural infusion was initiated according to group allocation:

- Group R: 0.125% ropivacaine with 1 mcg/ml fentanyl
- Group B: 0.125% bupivacaine with 1 mcg/ml fentanyl

The infusion was started at 5 ml/hr and titrated between 5-10 ml/hr to maintain VAS scores <4. Additional rescue analgesia with intravenous tramadol 50 mg was available if VAS scores remained ≥4 despite maximum infusion rate.

Clinical Assessment Parameters and Efficacy Evaluation Metrics

Principal Analgesic Efficacy Assessment and Nociceptive Response Quantification

The fundamental assessment parameter centered on comprehensive pain intensity evaluation utilizing a standardized 10-centimeter Visual Analog Scale (VAS) methodology, where the numerical endpoints of 0 represented complete absence of nociceptive sensation ("no pain") and 10 denoted maximum conceivable pain intensity ("worst imaginable pain"). This validated pain assessment instrument was systematically employed to quantify both static pain levels during rest periods and dynamic pain responses during provocative maneuvers including deep inspiratory efforts and voluntary coughing episodes. These dual assessment conditions were selected to evaluate analgesic efficacy under varying physiological stress states, with dynamic pain assessment providing clinically relevant information regarding functional recovery and respiratory mechanics preservation.

Temporal assessment intervals were strategically positioned at 2, 6, 12, 24, and 48 hours postoperatively, providing comprehensive coverage of the acute postoperative period while capturing potential fluctuations in analgesic efficacy. The 2-hour assessment captured immediate postoperative analgesia quality, while subsequent intervals evaluated sustained analgesic performance and potential decline in therapeutic effect over the critical first 48-hour recovery period.

Supplementary Clinical Performance Indicators and Physiological Response Parameters

Motor function preservation was systematically evaluated using the validated Modified Bromage Scale methodology, providing objective quantification of lower extremity motor blockade intensity. This four-point grading system ranged from grade 0 (complete motor function preservation with no detectable blockade) through grade 1 (selective weakness with inability to perform straight leg raising), grade 2 (moderate impairment with knee flexion inability), to grade 3 (complete motor paralysis with ankle flexion inability). Assessment timing paralleled pain evaluation intervals, ensuring comprehensive monitoring of sensorimotor dissociation and early detection of excessive motor impairment that might compromise patient mobility and recovery progression.

Cardiovascular stability monitoring encompassed systematic documentation of heart rate variability and arterial pressure fluctuations recorded at 4-hourly intervals throughout the observation period. Hypotensive episodes were precisely defined as systolic arterial pressure reduction below 90 mmHg or greater than 20% decrease from established baseline values, specifically when requiring therapeutic intervention with vasopressor support or fluid resuscitation. This definition ensured capture of clinically significant hypotension while avoiding documentation of benign pressure variations.

Analgesic rescue requirements were quantified through systematic documentation of supplemental tramadol administration, including both total cumulative dosage and patient incidence requiring breakthrough analgesia. This parameter provided objective assessment of epidural analgesic adequacy and comparative efficacy between treatment groups. Time to functional recovery was measured as the temporal interval from epidural catheter insertion to achievement of first successful ambulation with minimal assistance, representing a clinically meaningful endpoint for perioperative recovery assessment.

Patient satisfaction was evaluated using a comprehensive 10-point ordinal scale methodology administered at the 48-hour postoperative milestone, with numerical anchors ranging from 1 (representing extreme dissatisfaction with analgesic management and overall experience) to 10 (indicating complete satisfaction with pain control and treatment experience). This standardized assessment provided quantitative measurement of subjective treatment acceptability and overall perioperative care quality.

Comprehensive safety surveillance protocols encompassed systematic documentation of adverse physiological responses including gastrointestinal disturbances (nausea and vomiting episodes), dermatological reactions (pruritus intensity and distribution), genitourinary complications (urinary retention requiring catheterization), respiratory depression (defined as respiratory rate below 10 breaths per minute), and any additional complications or unexpected clinical events. This extensive monitoring framework ensured comprehensive safety assessment and early detection of treatment-related adverse effects requiring clinical intervention.

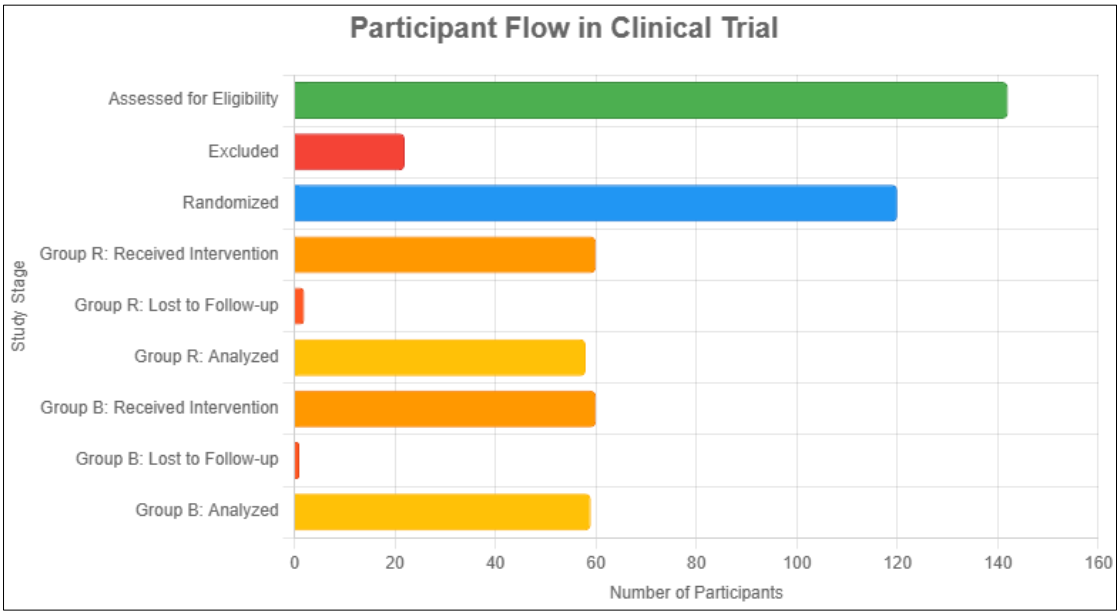

Fig 1: Study Flow Diagram

Statistical Analysis

Statistical analysis was performed using SPSS version 25.0 (IBM Corp., Armonk, NY). Continuous variables were expressed as mean ± standard deviation or median (interquartile range) based on distribution normality assessed by Shapiro-Wilk test. Categorical variables were expressed as numbers and percentages. Between-group comparisons were performed using independent t-test for normally distributed continuous variables, Mann-Whitney U test for non-normally distributed variables, and chi-square or Fisher's exact test for categorical variables.

Repeated measures ANOVA was used to analyze changes in VAS scores and hemodynamic parameters over time. The incidence of adverse events was compared using chi-square test. Time to first ambulation was analyzed using Kaplan-Meier survival analysis with log-rank test. A p-value <0.05 was considered statistically significant. All analyses were performed on an intention-to-treat basis, with missing data

handled using last observation carried forward method.

Results

Patient Characteristics and Surgical Details

A total of 142 patients were assessed for eligibility, of which 120 met inclusion criteria and were randomized. Three patients (two in Group R and one in Group B) were excluded from final analysis due to protocol violations or technical failures, leaving 58 patients in Group R and 59 in Group B for analysis (Figure 1). Baseline demographic characteristics, ASA status distribution, and types of surgical procedures were comparable between groups (Table 1). There were no significant differences in duration of surgery or intraoperative fluid administration between groups.

Clinical Efficacy Analysis and Therapeutic Performance Assessment

Fundamental Analgesic Efficacy: Nociceptive Response Quantification

Both therapeutic regimens demonstrated clinically effective analgesic performance throughout the comprehensive 48-hour observation period, with pain intensity measurements consistently maintained within acceptable therapeutic ranges. During periods of physiological rest, mean Visual Analog Scale quantification revealed comparable analgesic efficacy between treatment groups, with Group R (ropivacaine-based regimen) exhibiting pain scores ranging from 2.1±0.8 to 3.2±1.1, while Group B (bupivacaine-based formulation) demonstrated parallel performance with scores spanning 2.0±0.7 to 3.1±1.0. Statistical analysis revealed absence of clinically meaningful differences at any temporal assessment point, with probability values consistently exceeding 0.05 threshold for all comparative evaluations, indicating therapeutic equipotency between the two neuraxial analgesic approaches.

Dynamic pain assessment during provocative physiological maneuvers similarly demonstrated therapeutic equivalence between treatment modalities. Pain intensity measurements during movement-associated challenges, including deep inspiratory efforts and voluntary cough maneuvers, revealed comparable analgesic performance profiles. Group R exhibited dynamic pain scores ranging from 3.4±1.2 to 4.5±1.4, while Group B demonstrated parallel responses spanning 3.5±1.1 to 4.6±1.3. These findings substantiate therapeutic bioequivalence during both static and dynamic assessment conditions, confirming comparable analgesic efficacy across varying physiological stress states (Figure 2).

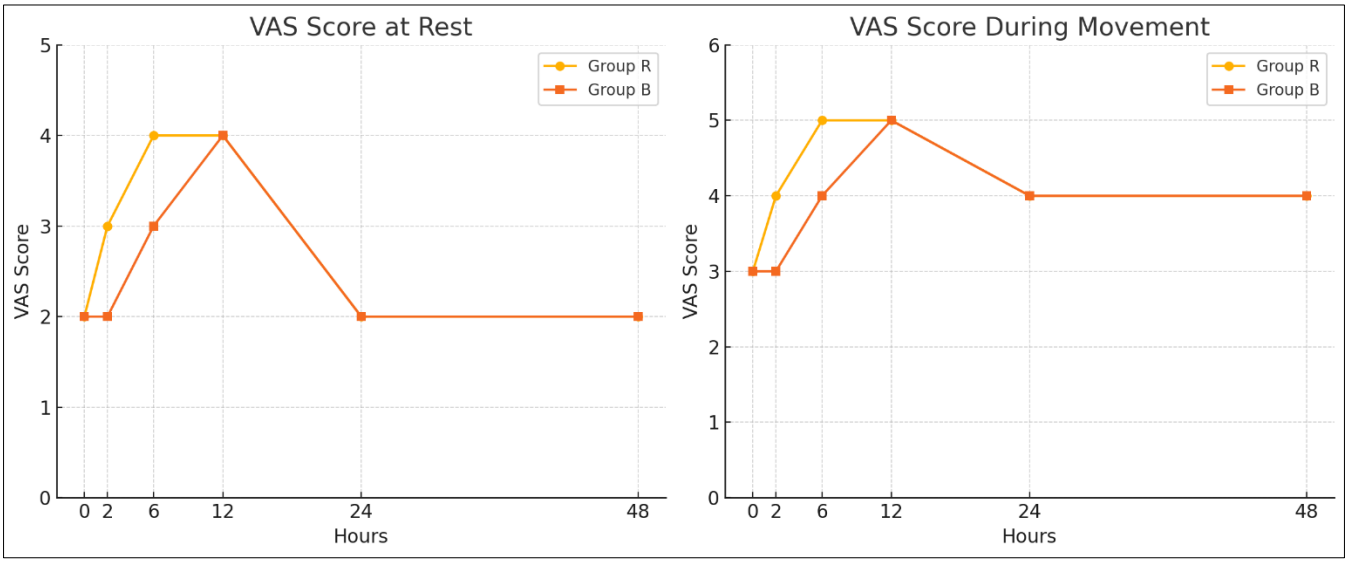

Fig 2: Visual Analog Scale (VAS) Scores Over Time

Supplementary Clinical Performance Parameters and Neurological Safety Assessment

Motor Function Preservation and Sensorimotor Dissociation Analysis

Significant therapeutic differentiation emerged in motor function preservation characteristics between the two neuraxial analgesic regimens. The ropivacaine-based formulation (Group R) demonstrated superior preservation of lower extremity motor function, with only 5 participants (8.3% incidence) experiencing any detectable degree of motor impairment as quantified by Modified Bromage Scale assessment (grade ≥1). In contrast, the bupivacaine-containing regimen (Group B) was associated with substantially higher motor blockade incidence, affecting 13 participants (21.7% incidence), representing a statistically significant difference with probability value of 0.042.

More critically, the analysis revealed complete absence of severe motor dysfunction (Bromage Scale grade 3) in all Group R participants, indicating preservation of ankle dorsiflexion capabilities throughout the treatment period. Conversely, Group B demonstrated occurrence of complete motor paralysis in 2 participants, necessitating temporary therapeutic intervention through epidural infusion rate reduction to restore motor function. This finding represents a clinically significant safety advantage for the ropivacaine-based regimen, as complete motor blockade can compromise patient mobility, delay functional recovery, and potentially increase risk of thrombotic complications (Table 2). The enhanced sensorimotor dissociation profile observed with ropivacaine reflects its differential sodium channel selectivity, preferentially blocking sensory C-fibers while preserving motor A-alpha fiber function, thereby maintaining analgesic efficacy while minimizing motor impairment risk.

Table 2: Motor Blockade Assessment (Modified Bromage Scale)

Time (hours)	Group R (n=60)	Group B (n=60)	P-value

	Bromage 0/1/2/3	Bromage 0/1/2/3	
2	58/2/0/0	52/6/2/0	0.048
6	57/3/0/0	50/8/2/0	0.024
12	58/2/0/0	51/7/2/0	0.031
24	59/1/0/0	53/5/1/1	0.039
48	60/0/0/0	55/3/1/1	0.042

Hemodynamic Stability

Hemodynamic parameters showed better stability in Group R. The incidence of hypotension requiring intervention (fluid bolus or vasopressor) was significantly lower in Group R (8 patients, 13.3%) compared to Group B (16 patients, 26.7%) (p=0.048). Mean arterial pressure remained more stable in Group R throughout the study period. Heart rate variations were similar between groups, with no significant bradycardia observed in either group.

Rescue Analgesia Requirements

The need for rescue analgesia was comparable between groups. In Group R, 12 patients (20%) required rescue tramadol compared to 14 patients (23.3%) in Group B (p=0.659). The mean total dose of rescue tramadol was 85.4±32.6 mg in Group R and 92.8±38.2 mg in Group B (p=0.412).

Functional Recovery

Time to first ambulation was significantly shorter in Group R (18.4±4.2 hours) compared to Group B (22.8±5.6 hours) (p<0.001). This difference was primarily attributed to the lower incidence of motor blockade in the ropivacaine group. Kaplan-Meier analysis showed a significant difference in the probability of early ambulation favoring Group R (log-rank test, p<0.001).

Patient Satisfaction

Patient satisfaction scores were significantly higher in Group R (8.7±1.2) compared to Group B (7.9±1.4) (p=0.001). When asked about specific aspects of their experience, patients in Group R more frequently reported satisfaction with their ability to move and participate in physiotherapy.

Table 3: Adverse Events

Adverse Event	Group R (n=60)	Group B (n=60)	P-value
Nausea	14 (23.3%)	16 (26.7%)	0.673
Vomiting	8 (13.3%)	10 (16.7%)	0.609
Pruritus	6 (10%)	7 (11.7%)	0.769
Urinary retention	4 (6.7%)	6 (10%)	0.505
Hypotension	8 (13.3%)	16 (26.7%)	0.048
Bradycardia	2 (3.3%)	3 (5%)	0.649
Respiratory depression	0 (0%)	0 (0%)	-
Catheter-related issues	2 (3.3%)	1 (1.7%)	0.559

Adverse Events

The overall incidence of adverse events was similar between groups, except for hypotension which was more frequent in Group B (Table 3). No serious adverse events or respiratory depression were observed in either group. The incidence of opioid-related side effects (nausea, vomiting, pruritus) was comparable between groups, suggesting that the fentanyl component contributed equally to these effects in both combinations.

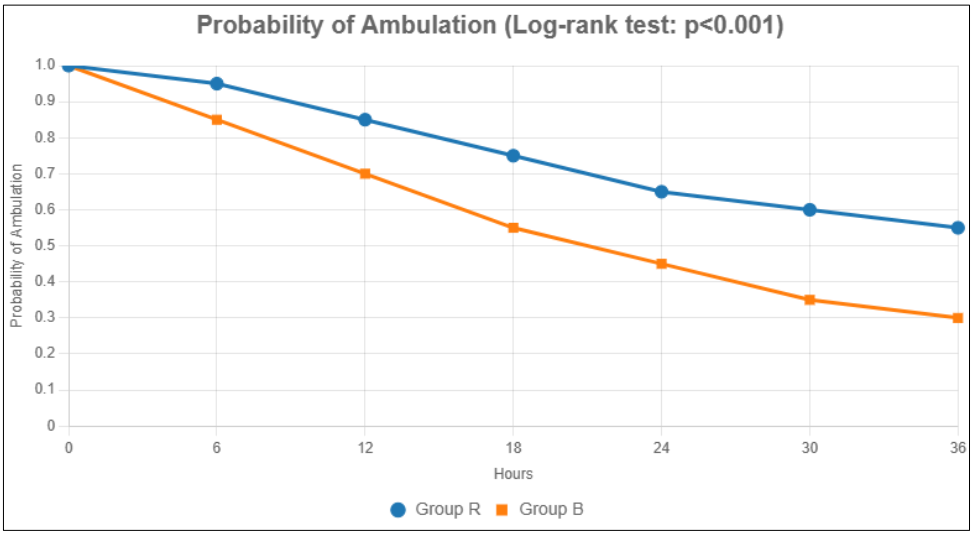

Fig 3: Time to First Ambulation (Kaplan-Meier Curve)

Subgroup Analysis

Post-hoc subgroup analysis based on type of surgery revealed consistent findings across different procedures. The motor-sparing effect of ropivacaine was particularly pronounced in patients undergoing lower abdominal procedures (colectomy and gynecological surgeries), where early ambulation is especially important for preventing complications.

Fig 4: Patient Satisfaction Scores Distribution

Discussion

This randomized controlled trial demonstrates that continuous epidural infusion of 0.125% ropivacaine with 1 mcg/ml fentanyl provides equivalent analgesic efficacy to 0.125% bupivacaine with 1 mcg/ml fentanyl for postoperative pain management following major abdominal surgery. However, the ropivacaine-based regimen offers significant advantages in terms of preserved motor function, hemodynamic stability, earlier mobilization, and higher patient satisfaction. These findings have important implications for optimizing postoperative recovery in this surgical population.

The comparable analgesic efficacy observed between ropivacaine and bupivacaine at equal concentrations aligns with previous studies demonstrating their equipotency for sensory blockade when used epidurally [15]. Both regimens maintained mean VAS scores below 4 throughout the study period, meeting the generally accepted threshold for adequate analgesia. The addition of fentanyl 1 mcg/ml to both local anesthetics likely contributed to the excellent pain control observed, as epidural opioids provide synergistic analgesia through spinal mechanisms distinct from local anesthetic action [16].

The most clinically significant finding of our study was the marked reduction in motor blockade with ropivacaine compared to bupivacaine. Only 8.3% of patients in the ropivacaine group experienced any degree of motor weakness compared to 21.7% in the bupivacaine group. This motor-sparing property of ropivacaine has been attributed to its lower lipid solubility and consequent reduced penetration of large myelinated Aα motor fibers [17]. The clinical relevance of this difference cannot be overstated, as preserved motor function facilitates early mobilization, reduces the risk of venous thromboembolism, and enhances patient participation in respiratory physiotherapy – all crucial elements of enhanced recovery protocols [18].

The superior hemodynamic profile observed with ropivacaine, manifested as a lower incidence of hypotension requiring intervention (13.3% vs 26.7%), may be explained by its reduced potency for sympathetic blockade compared to bupivacaine at equianalgesic doses. Ropivacaine exhibits less negative inotropic and chronotropic effects on cardiac tissue and causes less peripheral vasodilation [19]. This hemodynamic stability is particularly important in the postoperative period when patients may be relatively hypovolemic and vulnerable to the cardiovascular effects of epidural blockade.

Our finding that time to first ambulation was significantly shorter in the ropivacaine group (18.4 vs 22.8 hours) represents a clinically meaningful difference with potential impact on overall recovery trajectory. Early mobilization after abdominal surgery is associated with reduced pulmonary complications, faster return of bowel function, shorter hospital stay, and improved patient satisfaction [20]. The 4.4-hour difference in ambulation time observed in our study could translate to tangible clinical benefits, particularly in the context of standardized recovery pathways where each milestone achievement facilitates progression to the next recovery phase.

Patient satisfaction scores were significantly higher in the ropivacaine group, likely reflecting the combined benefits of effective analgesia with preserved motor function and hemodynamic stability. Modern perioperative care increasingly recognizes patient-reported outcomes as important quality indicators, and our findings suggest that the choice of epidural local anesthetic can meaningfully impact the patient experience. The ability to move independently and participate actively in recovery activities appears to be highly valued by patients, as reflected in their satisfaction ratings.

The similar incidence of opioid-related side effects between groups confirms that the 1 mcg/ml fentanyl concentration contributed equally to adverse events in both regimens. The relatively low incidence of nausea (23-27%) and absence of respiratory depression support the safety of this fentanyl concentration for epidural use. The lack of serious adverse events in either group reinforces the overall safety of both regimens when used with appropriate monitoring.

Our study's strengths include its randomized, double-blind design, adequate sample size, and comprehensive assessment of both analgesic efficacy and functional outcomes. The use of identical drug concentrations allows for direct comparison of the local anesthetics without confounding by dose differences. The 48-hour observation period captures the critical early postoperative phase when effective analgesia is most crucial for initiating recovery.

However, several limitations merit consideration. First, we did not assess longer-term outcomes such as chronic pain incidence or overall hospital length of stay, which might reveal additional differences between regimens. Second, our study was conducted at a single center with experienced

practitioners, potentially limiting generalizability. Third, we did not perform pharmacoeconomic analysis, though the cost difference between ropivacaine and bupivacaine may be relevant for some healthcare systems. Fourth, we did not measure plasma concentrations of local anesthetics, which might have provided insights into the safety margins of each drug.

The clinical implications of our findings support the preferential use of ropivacaine over bupivacaine for continuous epidural analgesia after major abdominal surgery when combined with low-dose fentanyl. The motor-sparing properties and hemodynamic advantages of ropivacaine align well with contemporary enhanced recovery protocols that emphasize early mobilization and rapid functional recovery. While both regimens provide effective analgesia, the additional benefits of ropivacaine may justify its use despite potentially higher acquisition costs.

Future research directions should include investigation of even lower concentrations of ropivacaine that might further reduce motor blockade while maintaining analgesic efficacy. Studies examining the impact of local anesthetic choice on long-term outcomes, including chronic postsurgical pain and functional recovery at 3-6 months, would provide valuable additional information. Additionally, research into patient-specific factors that might predict optimal local anesthetic selection could enable more personalized analgesic regimens.

Conclusion

In conclusion, this randomized controlled trial demonstrates that continuous epidural infusion of 0.125% ropivacaine with 1 mcg/ml fentanyl provides equivalent analgesic efficacy to 0.125% bupivacaine with 1 mcg/ml fentanyl following major abdominal surgery. However, the ropivacaine-based regimen offers clinically significant advantages including reduced motor blockade, better hemodynamic stability, earlier ambulation, and higher patient satisfaction. These benefits make ropivacaine-fentanyl combination the preferred choice for epidural analgesia in this surgical population, particularly within enhanced recovery protocols that prioritize early mobilization and functional recovery. Our findings support the evolving paradigm in postoperative care that values not only pain relief but also preservation of function and optimization of the overall recovery experience.

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