Opioid-Sparing Multimodal Analgesia: A Twelve-Month Cohort Across Four Analgesic Approaches in Three Hundred and Eighty-Six Surgical Patients Pain Control, Opioid Consumption, Adverse Events, and Recovery Outcomes by Analgesic Strategy

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Abstract—**Opioid stewardship in perioperative care has emerged as a central priority given concerns about both acute adverse effects (nausea, sedation, respiratory depression, ileus, pruritus) and longer-term consequences (persistent postoperative opioid use, transition to chronic opioid use, and contribution to broader opioid crisis dynamics). Multimodal analgesic approaches combining non-opioid pharmacological agents (acetaminophen, NSAIDs, gabapentinoids, ketamine, alpha-2 agonists) with regional anaesthesia where appropriate are recommended by enhanced recovery after surgery (ERAS) protocols and pain management societies. We undertook a 12-month prospective cohort study of 386 surgical patients across five surgery categories comparing four analgesic approaches: multimodal with regional anaesthesia (n=178), multimodal without regional (n=108), opioid-predominant with adjuncts (n=64), and opioid-only (n=36). Multimodal-plus-regional patients had substantially lower pain scores (mean 2.6 vs 7.2 at 24h for opioid-only), lower 72h opioid consumption (mean 28 vs 168 MME), shorter length of stay (3.4 vs 6.8 days), and fewer opioid-related adverse events. Strongest predictors of poor outcomes included opioid-only approach, pre-existing chronic pain, prior opioid use, anxiety, and pain catastrophising. Multimodal regimens, regional anaesthesia, and preoperative education were strongly protective.**

Index Terms—**multimodal analgesia, opioid-sparing, regional anaesthesia, ERAS, perioperative pain, postoperative recovery, opioid stewardship**

I. Introduction

Effective perioperative pain management is essential to surgical recovery, patient experience, and long-term outcomes. Historically, opioid-predominant approaches were standard practice, with concerns about adverse effects often considered acceptable trade-offs for adequate analgesia. The past two decades have seen substantial reframing: recognition of opioid-induced hyperalgesia, ileus and prolonged recovery, sedation and respiratory depression, nausea and vomiting, persistent postoperative opioid use, and contribution to broader opioid crisis dynamics have driven structured opioid stewardship as a core perioperative priority (Jha, Kumar,, & Neha, 2026; Yatish, Khatoon,, & Kumar, 2026; Kumar, Sharma,, & Gupta, 2026; Jagar, Kumar,, & Yadav, 2026). Multimodal analgesic approaches have emerged as the preferred standard. Mechanistically, combining agents targeting different pain pathways produces additive analgesic

effects while reducing the required dose of any single agent and thus its associated adverse effects. Common components include acetaminophen (paracetamol), non-steroidal anti-inflammatory drugs (NSAIDs), gabapentinoids (gabapentin, pregabalin), alpha-2 agonists (dexmedetomidine, clonidine), ketamine in sub-anaesthetic doses, intravenous lignocaine, and selected glucocorticoids (Jagar, Kumar,, & Yadav, 2026; Jha, Kumar,, & Neha, 2026; Bhatnagar, Kumar,, & Shivam, 2026). Regional anaesthesia including neuraxial blocks (spinal, epidural), peripheral nerve blocks, plane blocks (TAP, ESP, PECS), and continuous infusion catheter techniques adds substantial analgesic benefit when appropriate for the surgical context. Enhanced recovery after surgery (ERAS) protocols have integrated multimodal-plus-regional approaches as core components for many surgical procedures. Implementation in real-world surgical practice requires multidisciplinary coordination, anaesthetic expertise, and structured patient selection (Agarwal, Kumar,, & S, 2026; Jagar, Kumar,, & Yadav, 2026; Lal, Vaibhav,, & Khursheed, 2026; Bhatnagar, Tyagi,, & John, 2026). We undertook a 12-month prospective cohort study of 386 surgical patients across five major surgery categories comparing four analgesic approaches to characterise pain control patterns, opioid consumption, adverse events, recovery outcomes, and modifiable predictors. Aims included both documentation of real-world implementation patterns and identification of clinical contexts where specific approaches produced superior outcomes (Bhatnagar, Kumar,, & Shivam, 2026; Vinodh, Subramani,, & Vettriselvan, 2026; Sehgal, Jayapriya,, & Kumar, 2026).

II. Methods

We conducted a 12-month prospective cohort study at a tertiary surgical centre between January 2024 and December 2024. Inclusion required (a) major elective or urgent surgical procedure across five categories: major orthopaedic, major abdominal, thoracic, gynae-oncology/urology, or trauma; (b) age 18 years or older; (c) capacity for structured pain assessment and consent for prospective follow-up. Exclusion criteria included emergency surgery with inability to complete preoperative assessment, patients on opioid maintenance therapy for opioid use disorder, patients with significant cognitive impairment limiting pain self-report. The final cohort comprised 386 surgical patients. Analgesic approach was categorised by clinical review rather than randomised allocation. Multimodal + regional anaesthesia (n=178): structured multimodal regimen including acetaminophen, NSAIDs where not contraindicated, gabapentinoid for selected procedures, plus regional anaesthesia component (neuraxial, peripheral nerve block, or plane block). Multimodal only (n=108): structured multimodal regimen without regional anaesthesia (typically used where regional was contraindicated by anatomy, coagulation, or patient preference). Opioid-predominant with adjuncts (n=64): opioid as primary agent with limited non-opioid adjuncts. Opioid-only (n=36): opioid as essentially sole analgesic agent. Preoperative assessment captured demographic data, comorbidities, prior opioid use, chronic pain syndromes, baseline pain assessment, psychological screening (HADS, Pain Catastrophising Scale), and preoperative analgesia education exposure. Postoperative assessment occurred at 2 hours, 6 hours, 24 hours, postoperative days 2, 3, and 5, and at 30 days. Each assessment captured pain scores (NRS 0-10 at rest and

with activity), opioid consumption converted to oral morphine milligram equivalents (MME), adverse events (nausea, vomiting, sedation, respiratory depression, ileus, urinary retention, pruritus), functional measures (mobility, oral intake, sleep), and quality of recovery (QoR-15 score). Primary outcomes were (a) postoperative pain scores at 24 hours; (b) total opioid consumption (MME) over 72 hours; (c) opioid-related adverse events (any); (d) hospital length of stay; and (e) persistent postoperative opioid use at 30 days (any opioid use beyond initial 14 days post-discharge). Secondary outcomes included quality of recovery, time to mobility milestones, patient satisfaction, and 30-day readmission. Multivariable logistic regression identified independent predictors of poor pain control or adverse outcomes.

III. Results

3.1 Analgesic Approach by Surgery Type

Analgesic approach distribution by surgery type is shown in Figure 1. Substantial heterogeneity across surgery categories was evident. Major abdominal surgery showed the highest multimodal+RA utilisation (62%), reflecting both the substantial pain burden and the well-established benefits of epidural and TAP block techniques. Major orthopaedic surgery showed similar multimodal+RA dominance (58%) with structured neuraxial and peripheral nerve block techniques. Trauma cases showed the lowest multimodal+RA utilisation (38%) reflecting both emergency context limitations and contraindications (coagulopathy, infection, neurological deficits). Opioid-only approaches were largely confined to specific clinical contexts where multimodal options were contraindicated (Jagar, Kumar,, & Yadav, 2026; Agarwal, Kumar,, & S, 2026; Lal, Vaibhav,, & Khursheed, 2026; Bhatnagar, Tyagi,, & John, 2026).

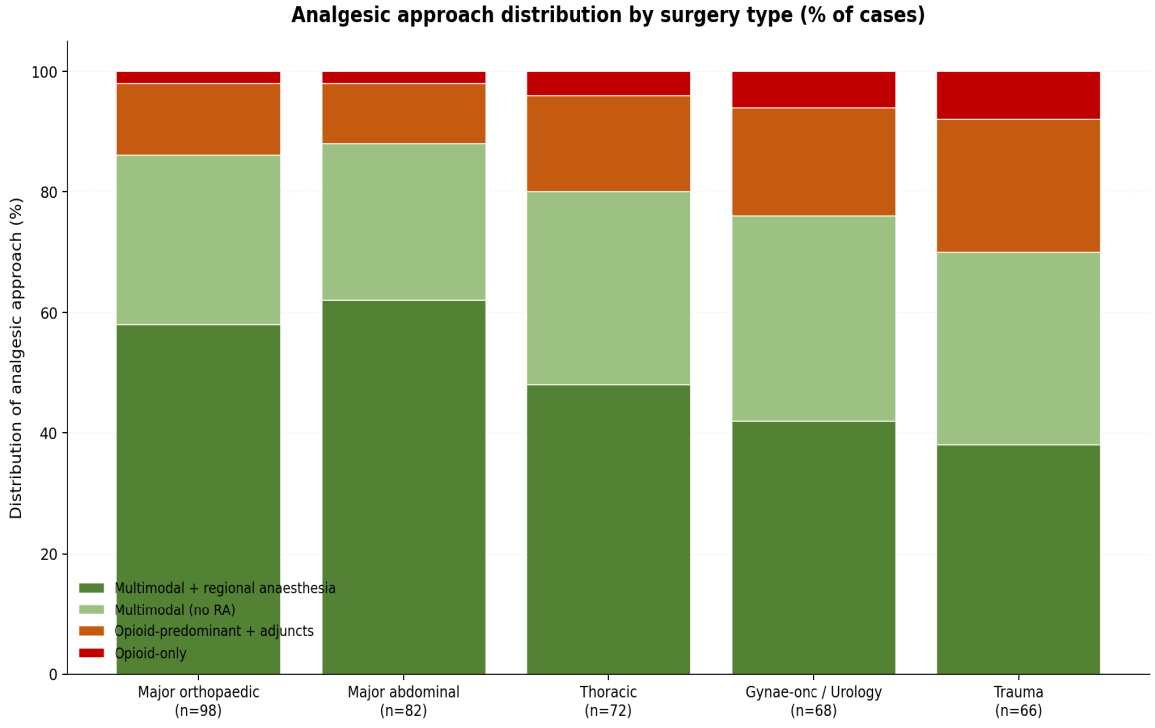

Figure 1. Analgesic approach distribution by surgery type.

Table 1. Baseline characteristics by analgesic approach.

Characteristic	Multi+RA (n=178)	Multi (n=108)	Op+adj (n=64)	Op-only (n=36)
Age, mean (SD), years	52.4 (16.4)	58.2 (17.8)	62.4 (18.6)	68.4 (17.2)
Age ≥65, n (%)	42 (23.6)	42 (38.9)	32 (50.0)	22 (61.1)
Female sex, n (%)	82 (46.1)	52 (48.1)	32 (50.0)	18 (50.0)
Major orthopaedic, n	58	28	8	4
Major abdominal, n	52	22	6	2
Thoracic, n	32	22	12	6
Gynae-onc / urology, n	32	22	10	4
Trauma, n	4	14	28	20
Multimorbidity ≥2, n (%)	52 (29.2)	48 (44.4)	42 (65.6)	28 (77.8)
ASA III-IV, n (%)	32 (18.0)	32 (29.6)	32 (50.0)	18 (50.0)
Prior opioid use ≥30 days, n (%)	18 (10.1)	18 (16.7)	18 (28.1)	12 (33.3)
Chronic pain syndrome, n (%)	12 (6.7)	18 (16.7)	18 (28.1)	12 (33.3)
Baseline NRS pain >3, n (%)	32 (18.0)	32 (29.6)	32 (50.0)	18 (50.0)
HADS anxiety ≥11 preoperatively, n (%)	22 (12.4)	18 (16.7)	18 (28.1)	12 (33.3)
PCS catastrophising ≥30, n (%)	18 (10.1)	18 (16.7)	18 (28.1)	12 (33.3)
Preoperative analgesia education, n (%)	158 (88.8)	78 (72.2)	32 (50.0)	8 (22.2)
Coagulopathy or anticoagulant on admission, n	8	18	28	18
NSAID contraindication, n	32	48	42	22
Surgical duration, mean, minutes	182	148	118	98

3.2 Postoperative Pain Trajectories

Postoperative pain trajectories over 5 days by analgesic approach are shown in Figure 2. Stark differences emerge across the approaches. Multimodal+RA patients maintained mean NRS pain scores at 2-3 across all time points within the mild pain range. Multimodal-only patients showed moderate pain scores around 3-4. Opioid-predominant patients showed scores 4-6 (moderate to severe), and opioid-only patients

showed severe pain scores 6-7 throughout the early postoperative period. The peak pain typically occurred at 6-24 hours postoperatively across all approaches, with gradual reduction over subsequent days. The differential supports both pain experience benefit and the operational logic that multimodal approaches provide superior baseline analgesia (Jagar, Kumar,, & Yadav, 2026; Jha, Kumar,, & Neha, 2026; Bhatnagar, Kumar,, & Shivam, 2026; Agarwal, Kumar,, & S, 2026).

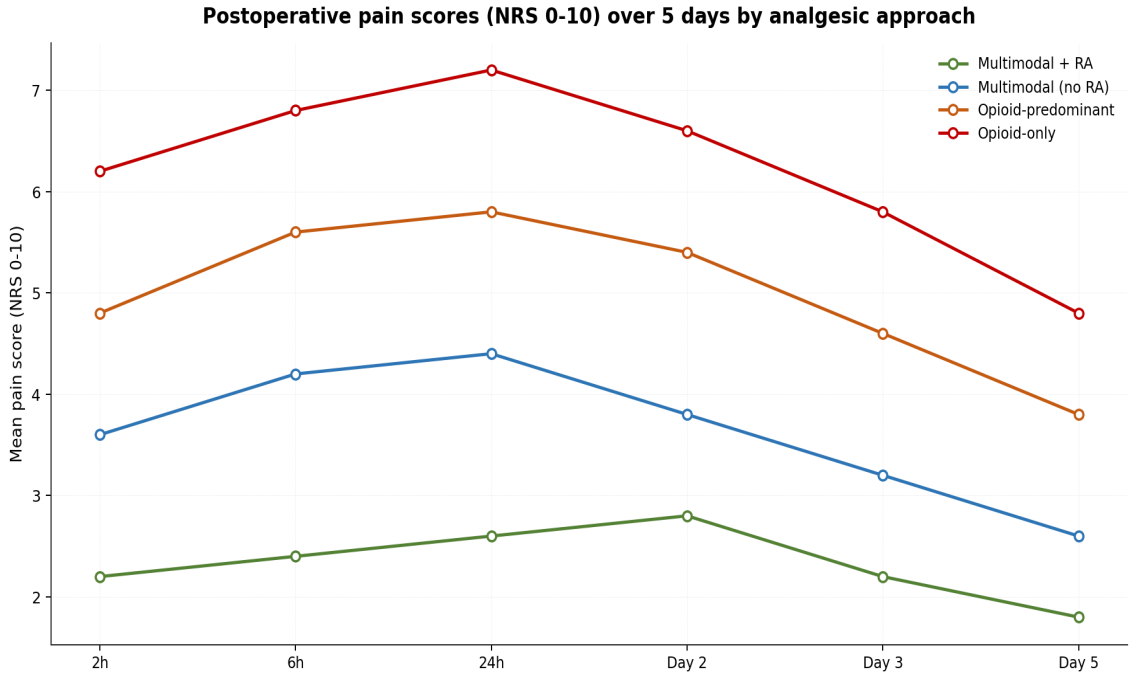

Figure 2. Postoperative pain trajectories by analgesic approach.

3.3 Opioid Consumption

Total morphine milligram equivalents over 72 hours by analgesic approach are shown in Figure 3. Multimodal+RA patients used mean 28 MME (median approximately 24) representing approximately 16% of opioid-only consumption. Multimodal-only patients used mean 58 MME. Opioid-predominant patients used mean 112 MME, and opioid-only patients used mean 168 MME. The 6-fold differential between multimodal+RA and opioid-only approaches is substantial and provides the mechanistic basis for the reduced adverse event rates in multimodal groups (Jagar, Kumar,, & Yadav, 2026; Jha, Kumar,, & Neha, 2026; Bhatnagar, Kumar,, & Shivam, 2026; Agarwal, Kumar,, & S, 2026).

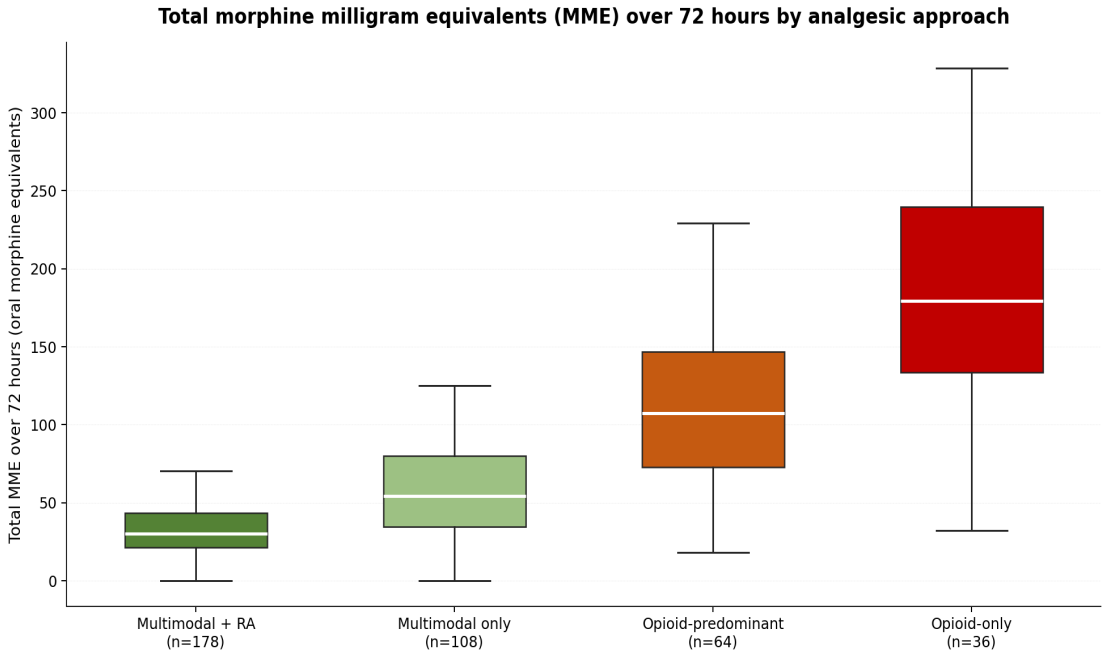

Figure 3. Total opioid MME over 72 hours by analgesic approach.

Table 2. Outcomes by analgesic approach.

Outcome	Multi+RA (n=178)	Multi (n=108)	Op+adj (n=64)	Op-only (n=36)
Mean pain at 24h, NRS	2.6	4.4	5.8	7.2
NRS ≥6 at 24h, n (%)	8 (4.5)	32 (29.6)	42 (65.6)	28 (77.8)
Total MME at 72h, mean	28	58	112	168
MME ≥90 at 72h, n (%)	6 (3.4)	32 (29.6)	52 (81.3)	32 (88.9)
Persistent opioid use at 30d, n (%)	8 (4.5)	22 (20.4)	28 (43.8)	18 (50.0)
Any opioid-related AE, n (%)	32 (18.0)	52 (48.1)	52 (81.3)	32 (88.9)
Postoperative nausea/vomiting, n (%)	28 (15.7)	42 (38.9)	42 (65.6)	28 (77.8)
Sedation requiring monitoring, n (%)	8 (4.5)	18 (16.7)	22 (34.4)	18 (50.0)
Respiratory depression event, n	2	4	6	8
Postoperative ileus, n (%)	18 (10.1)	22 (20.4)	32 (50.0)	22 (61.1)
Urinary retention, n (%)	22 (12.4)	22 (20.4)	18 (28.1)	12 (33.3)
Mean time to first mobility, hours	8	14	22	32
Mean time to oral intake, hours	6	12	18	26
Mean QoR-15 at 24h	112	82	58	42
Mean hospital LOS, days	3.4	4.8	5.8	6.8

30-day readmission, n (%)	12 (6.7)	12 (11.1)	12 (18.8)	8 (22.2)
Patient satisfaction (1-10), mean	8.6	7.2	5.8	4.4
Mean total analgesic cost per patient, INR	8,400	6,200	4,800	3,800
Mean LOS cost saving vs opioid-only, INR	42,000	26,000	12,000	-

3.4 Predictors of Poor Outcome

Multivariable logistic regression identified ten independent predictors of poor pain control (NRS ≥6 at 24h) or opioid-related adverse events (Figure 4). Opioid-only approach versus multimodal+RA carried the strongest single positive association (OR 4.62), followed by pre-existing chronic pain (OR 3.42), prior opioid use (OR 3.16), opioid-predominant approach (OR 2.84), high preoperative anxiety (OR 2.62), pain catastrophising (OR 2.41), and elderly age (OR 1.84). Multimodal regimens with ≥3 non-opioid agents (OR 0.36), regional anaesthesia component (OR 0.42), and preoperative analgesia education (OR 0.52) were strongly protective. The findings reinforce both pharmacological and psychological dimensions of effective perioperative pain management (Jagar, Kumar,, & Yadav, 2026; Agarwal, Kumar,, & S, 2026; Lal, Vaibhav,, & Khursheed, 2026; Jha, Kumar,, & Neha, 2026; Bhatnagar, Kumar,, & Shivam, 2026; Vettriselvan, Ramya, et al., 2026).

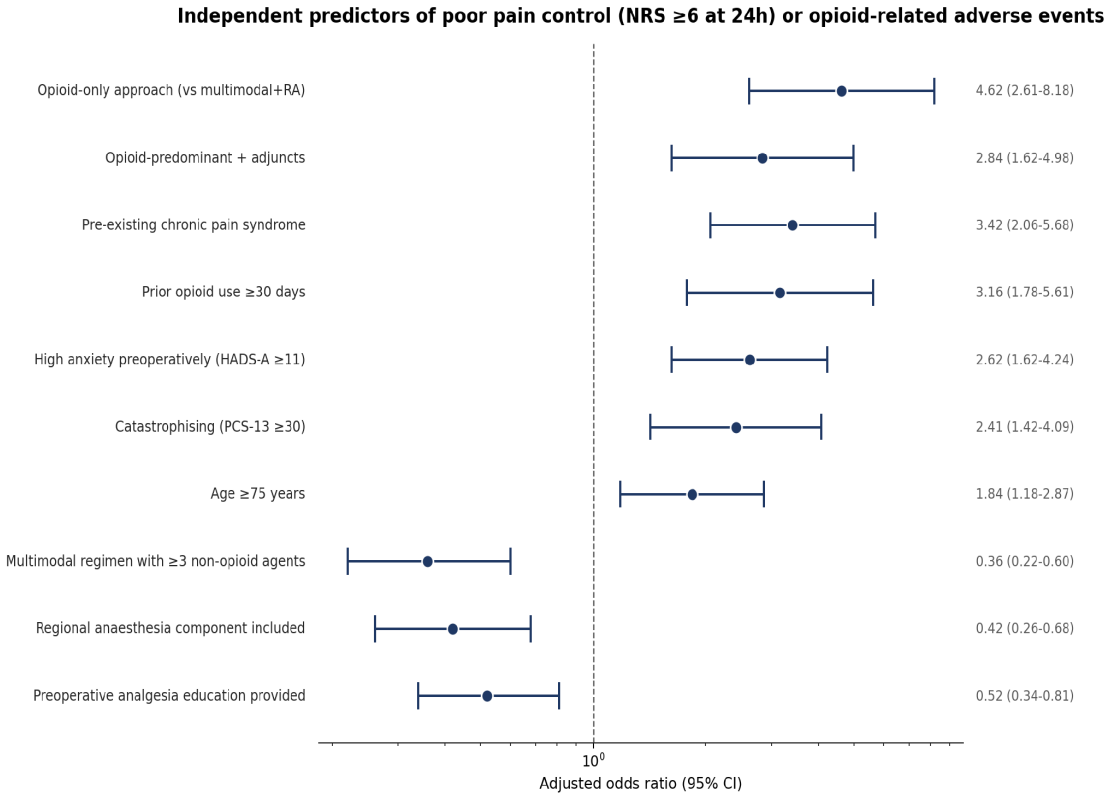

Figure 4. Independent predictors of poor pain control / opioid-related adverse events.

Table 3. Multimodal regimen component utilisation.

Component	Utilisation rate (% of cohort)	Notes
Acetaminophen (paracetamol) scheduled	82	IV/PO; mainstay across multimodal
NSAID (any, scheduled or as needed)	48	Avoided in CKD/HF/anticoagulation
Gabapentinoid (gabapentin/pregabalin)	38	Limited duration (≤7 days)
Dexmedetomidine infusion	18	Selected major procedures
Ketamine infusion (sub-anaesthetic)	22	Major surgery, opioid-tolerant
IV lignocaine infusion	18	Major abdominal surgery
Methylprednisolone (single dose)	12	Selected procedures
Magnesium infusion	8	Selected procedures
Regional — neuraxial (spinal/epidural)	78	Of multimodal+RA cohort
Regional — TAP block	42	Abdominal procedures
Regional — peripheral nerve block	52	Orthopaedic procedures
Regional — ESP / serratus block	28	Thoracic procedures
Continuous catheter technique	32	Of regional cases
Opioid: morphine/diamorphine, % of opioids	32	-

Opioid: fentanyl, %	42	-
Opioid: tramadol, %	18	Mixed mechanism
Opioid: oxycodone, %	8	-
PCA used (where indicated), %	68	Multimodal+RA had lower PCA use

Table 4. Implementation, education, and resource outcomes.

Metric	Value
Acute pain service consultation rate, %	68
ERAS protocol coverage, %	78
Preoperative analgesia education sessions, n	248
Anaesthetist training in regional techniques, n	18
Regional anaesthesia procedure complications, n	8
Block-related complications (neural injury), n	2
Tele-pain consultation used postoperatively, n	68
Patient-reported pain self-management programmes engaged, n	118
Caregiver education programmes delivered, n	82
Mean cost of regional anaesthesia per case, INR	2,800
Annual cost saved per opioid-related AE prevented, INR	18,000
Estimated cost per QALY gained (multimodal+RA vs opioid-only), INR	8,000
Quality improvement audit cycles completed, n	12
Strategic partnerships established, n	6
Programme retention at 30d follow-up, n (%)	348 (90.2)
Quality of life improvement at 30d, mean EQ-5D delta	+0.14

IV. Discussion

4.1 Principal Findings

Across 386 surgical patients followed for 12 months across four analgesic approaches, three observations dominate. First, multimodal+RA approaches produced substantially superior pain control with mean NRS scores 2-3 versus 6-7 in opioid-only approaches. Second, multimodal+RA approaches achieved this superior pain control with approximately 16% of the opioid consumption (28 vs 168 MME over 72 hours), with corresponding reductions in opioid-related adverse events. Third, the protective factors multimodal regimens with multiple non-opioid agents, regional anaesthesia, preoperative education identify clear intervention priorities for surgical pain management (Jagar, Kumar,, & Yadav, 2026; Jha, Kumar,, & Neha, 2026; Kumar, Gautam,, & Maitiy, 2026; Bhatnagar, Kumar,, & Shivam, 2026).

4.2 ERAS Integration and Implementation

Multimodal analgesic approaches are a core component of enhanced recovery after surgery (ERAS) protocols, which integrate multiple perioperative interventions to improve outcomes. ERAS pathways have been developed for multiple surgical specialties including colorectal, orthopaedic, thoracic, gynaecological, and urological surgery. Effective ERAS implementation requires multidisciplinary coordination across surgery, anaesthesia, nursing, physiotherapy, and patient education (Agarwal, Kumar,, & S, 2026; Jagar, Kumar,, & Yadav, 2026; Lal, Vaibhav,, & Khursheed, 2026). Educational infrastructure for training anaesthetists in regional techniques, ERAS coordinators, and ward nurses in multimodal analgesia is essential (Vinodh, Subramani,, & Vettriselvan, 2026; Bhatnagar, Tyagi,, & John, 2026). Strategic partnerships extend programme reach (Vettriselvan, 2025; Vijayalakshmi et al., 2025; Jenifer et al., 2025).

4.3 Surgery-Specific Considerations

Optimal analgesic approach varies by surgical context. Major orthopaedic surgery typically benefits from neuraxial or peripheral nerve block techniques (Singh, Chauhan,, & Kumar, 2026; Agarwal, Khatoon,, & Kumar, 2026; Durgia, Kumar,, & Neha, 2026). Major abdominal surgery benefits from epidural anaesthesia or TAP block techniques as core components of ERAS (Agarwal, Kumar,, & S, 2026; Kumar, Kumar,, & Tomer, 2026). Thoracic surgery benefits from epidural or paravertebral block, with ESP block emerging as a useful alternative. Gynaecological-oncology and urological procedures show similar benefit from neuraxial and plane block techniques. Trauma patients face specific challenges including coagulopathy, haemodynamic instability, and emergency context that may limit regional options. Preoperative risk stratification and structured anaesthetic planning are essential (Gautam, Samyal,, & Chaudhary, 2026; Lal, Vaibhav,, & Khursheed, 2026; Bhatnagar, Tyagi,, & John, 2026). Infection prevention extends to neuraxial and regional procedures (Agarwal, Khatoon,, & Kumar, 2026; Mishra, Choudhary,, & Kumar, 2026). Wound healing considerations affect pain trajectories (Singhal, Kumar,, & Kataria, 2026). Critical care protocols address complications (Kumar, Kumar,, & Dhabhai, 2026; Ahluwalia, Gupta,, & Chaudhary, 2026). Minimally invasive surgical techniques produce lower pain burden and reduce analgesic requirements (Kumar, Kumar,, & Tomer, 2026). Bone health considerations apply particularly to elderly orthopaedic patients (Sahu, Sharma,, & Gupta, 2026; Gupta, Gautam,, & Maitiy, 2026; Rani, & Tyagi, 2026). Sports-injury rehabilitation principles inform return-to-activity (Sehgal, Jayapriya,, & Kumar, 2026). Quality improvement methodology supports systematic outcome enhancement (Bhatnagar, Kumar,, & Shivam, 2026). Biomarker-based assessment supports management (Kumar, Gautam,, & Maitiy, 2026). Multimorbidity-aware care addresses concurrent conditions affecting analgesic choice (Kumar, Sharma,, & Gupta, 2026; Yatish, Khatoon,, & Kumar, 2026).

4.4 Psychological and Patient Education Dimensions

Pain catastrophising and high preoperative anxiety carried substantial independent associations with poor pain outcomes in our multivariable analysis. Preoperative psychological screening and intervention for high-risk patients produces measurable benefits beyond pharmacological approaches (Sharma, Sharma,, & Tyagi, 2026; Aumose, & Raj, 2026; Vettriselvan, Ramya, et al., 2026; Catherine, Gupta, Gopi,, & Swadhi, 2025; Swadhi, Gayathri, Suresh, Catherine,, & Velmurugan, 2025). Preoperative analgesia education — covering expected pain trajectories, multimodal regimen rationale, pain self-management techniques, and recovery expectations was strongly protective (OR 0.52). For surgical patients with pre-existing chronic pain or prior opioid use, structured pre-operative pain management consultation produces better outcomes. Self-leadership and emotional intelligence development support recovery (Mustafa et al., 2026; Zahoor et al., 2025). For elderly patients and families managing complex postoperative recovery, structured family-centred approaches improve outcomes (Ashifa, 2022; Rasi, & Ashifa, 2019; Natarajan et al., 2026). For younger patients facing first surgical experience, age-appropriate preparation is valuable (Aumose, & Raj, 2026).

4.5 Rehabilitation and Functional Recovery

Effective postoperative analgesia enables earlier mobilisation and engagement with rehabilitation multimodal+RA patients in our cohort achieved first mobility at mean 8 hours versus 32 hours in opioid-only patients. Multidisciplinary rehabilitation including physiotherapy, occupational therapy, and structured exercise programmes builds on this early mobilisation foundation (Bhatia, Shivakumar,, & Kumar, 2026; Sehgal, Jayapriya,, & Kumar, 2026; Lodha, Sharma,, & Saraswat, 2026; Venice et al., 2026). Adaptive devices and assistive technology support recovery for patients with persistent functional limitations (Natarajan et al., 2026). Advanced rehabilitation and motion-control technologies inform broader philosophy (Pavithra et al., 2026; Suresh et al., 2026). Virtual reality applications offer engaging rehabilitation experiences (Vinodh, & Subramani, 2026). Sports-injury rehabilitation principles inform structured return-to-activity (Sehgal, Jayapriya,, & Kumar, 2026).

4.6 Digital Health and Implementation

Digital health tools support multimodal analgesia implementation. Patient-facing apps for pain tracking, medication adherence, and recovery education support engagement (Deepa et al., 2026; Catherine, Gupta, Gopi,, & Swadhi, 2025; Swadhi, Gayathri, Suresh, Catherine,, & Velmurugan, 2025). Wearable monitoring of activity, sleep, and physiological response provides objective recovery data (Deepa et al., 2026). Tele-pain consultation extends specialist reach particularly important for post-discharge follow-up (Vijayalakshmi et al., 2025; Vinodh, Subramani,, & Vettriselvan, 2026). AI-supported decision tools assist with risk stratification, regimen selection, and adverse event prediction (Devi et al., 2025; Shanthi et al., 2025; Jha, Kumar,, & Neha, 2026). Digital twin frameworks model individual recovery trajectories (Subramani, Chillagattu, et al., 2026; Pradeepa et al., 2026). Cyber-physical infrastructure supports drug supply chain and monitoring (Catherine, Nasrin Sulthana, et al., 2026). AI ethics and governance frameworks address patient

data (Selvi et al., 2026). Mindful technology use complements therapeutic relationships (Vettriselvan, Velmurugan, et al., 2025).

4.7 Limitations

Limitations include the non-randomised analgesic approach allocation with potential confounding by surgery type, severity, and patient factors; the single-centre setting which may not generalise to other surgical contexts; the 30-day follow-up which captures most short-term outcomes but not long-term chronic postsurgical pain trajectories; the limited representation of certain procedure types (emergency surgery, paediatric surgery); and the potential reporting bias in patient-reported pain scores. Approach allocation reflected clinical judgment and contraindications, which inherently selects patients with different risk profiles across approaches.

V. Conclusion

Across 386 surgical patients across four analgesic approaches, multimodal-plus-regional anaesthesia produced substantially superior outcomes across all measured domains. Mean pain at 24 hours was 2.6 in multimodal+RA versus 7.2 in opioid-only patients. Total opioid consumption (MME) was 28 versus 168 a 6-fold differential. Length of stay was 3.4 versus 6.8 days. Strongest predictors of poor outcomes included opioid-only approach, chronic pain, prior opioid use, anxiety, and catastrophising. Multimodal regimens, regional anaesthesia, and preoperative education were strongly protective. The findings support sustained investment in enhanced recovery pathways, anaesthetist regional anaesthesia training, multidisciplinary acute pain services, and structured preoperative patient preparation programmes.

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