EFFICACY OF MULTIMODAL ANALGESIA IN POSTOPERATIVE PAIN MANAGEMENT: A RANDOMIZED CONTROLLED TRIAL

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Abstract

The issue of postoperative pain is still one of the primary clinical problems, and it usually prolongs the recovery time, exposes patients to more opioids, and affects patient outcomes. This is a randomized controlled trial that assessed the effectiveness of multimodal analgesia versus conventional opioid-based postoperative pain management as a mixed-method study that used quantitative measures of analgesia and qualitative patient-reported recovery experiences. Adult postoperative patients undergoing elective abdominal and orthopedic surgery were randomly divided into two groups: conventional opioid-centered analgesia and multimodal regimen of non-opioid analgesics and regional techniques of anesthesia and adjunctive pharmacologic agents. The validated scales used to assess the level of pain (Visual Analog Scale, VAS, and Numerical Rating Scale, NRS) were applied, and opioid intake was translated to morphine milligram equivalents to work out opioid-sparing effects. Secondary outcomes comprised the parameters of physiological stability, score of sedation, adverse drug reactions, initial ambulation potential and feedback of subjective recovery through structured interviews. Findings showed that multimodal analgesia produced far fewer pain scores, lesser opioid needs, enhanced physiological stability and diminished adverse events. The qualitative results also demonstrated an increase in the level of patient comfort and increased mobility, increased sleep quality, and other satisfaction levels among the multimodal recipients. The combined review revealed that the efficacy of multimodal analgesia is more effective as it can activate many pain pathways at the same time, which helps the patient get well sooner and reduce the incidence of opioid-related side effects. These results confirm the wider clinical implementation of multimodal analgesia as a safer and more efficient standard of handling postoperative pain and the need to have procedure-specific analgesic protocols applied to individual patients to achieve optimal patient outcomes

Keywords: Multimodal Analgesia; Postoperative Pain; Randomized Controlled Trial; Opioid-Sparing; Pain Intensity; Recovery Outcomes; Regional Anesthesia; Physiological Stability; Patient Satisfaction; Analgesic Effectiveness.

INTRODUCTION

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Postoperative pain is a multifaceted physical response to the surgery, which continues to be one of the major difficulties in medicine. It tends to increase hospital stay, healthcare costs and poor patient satisfaction. Some of the undesirable side effects of opioid-based approaches, which may be the primary mode of treating pain, include breathing issues, nausea, constipation, and the possibility of addiction (Yeo et al., 2022). Hence, the need to find alternative pain management approaches that can effectively manage pain and minimize those unwanted impacts continues to rise (Yeo et al., 2022). The combination of various pain-killing medications and techniques that operate in various mechanisms has become one of the promising techniques of better management of pain after surgery and accelerating recovery (Huang et al., 2024). It is a combination of the effects of various types of drugs, including nonsteroidal anti-inflammatory drugs, local anaesthetics, and gabapentinoids. The aim is to make the pain relief more effective and require less opioids (Huang et al., 2024; Geng et al., 2021). The randomised controlled trial, which is proposed, will be directed at conducting an in-depth analysis of the efficiency of a particular method in terms of multimodal analgesia compared to the opioid-based procedures in patients undergoing different types of surgeries (Negm et al., 2025). The areas that will be considered in this study are pain intensity, opioid use, and patient satisfaction. It is grounded on previous research that showed that multimodal interventions can reduce opioid consumption in other surgeries like radical prostatectomy and orthopaedic hand surgery (Lee et al., 2023; Ilyas et al., 2023). Further research has also involved the effectiveness of use of various forms of pain killers in big abdominal and breast operations. The aim of this approach is to decrease the consumption of opioids as well as possibly diminish the risks of

chronic postoperative pain (Gedda et al., 2023; Huang and Ho, 2025). The present paper is targeted at justifying the applicability of multimodal treatment plans to clinical practice. It will do this by assessing their outcome on wider cohort of surgical patients and analyze their functional recovery outcome in the medium-term (Zhang et al., 2025). It is a general approach to pain management, the goal of which is to improve patient wellness and allow them to resume normal activities sooner (Jain et al., 2023; Kianian et al., 2024). The idea of multimodal analgesia is to stimulate various pain pathways concurrently. The concept of the approach is to reach an improved treatment of pain and reduce the opioid dose of an individual painkiller (Der et al., 2022). The strategy improves the synergistic analgesic effects and reduces significantly the opioid-craving (Alqarni et al., 2024; Negm et al., 2025). The ongoing opioid crisis in the United States highlights how important it is to be careful when using opioid to treat postoperative pain, and, therefore, multimodal analgesia is particularly relevant (Sherman et al., 2020; Ilyas et al., 2023). The null hypothesis of the present study is that the full-scale pain management method with a high number of techniques will result in a radical reduction of consumption of opioids and the patient-reported outcomes, in comparison with the use of opioid-based methods to manage postoperative pain that are commonly utilized (Ilyas et al., 2023). The specified strategy is expected to reduce the chances of opioids overuse, which can potentially entail adding dependence and other negative outcomes and implement alternative drug therapies (Fernandes et al., 2024). This multimodal approach tends to combine the systemic medications with the local ones in a bid to offer some of the effective pain treatment. Using the case of brain surgery, a comparison of the severity of conventional opioid management and the approach of opioid sparing,

e.g., scalp blocks, in the treatment of pain has proved this (Negm et al., 2025). In this study, we will evaluate the alteration in multimodal analgesia on the use of opioids in patients during the post-surgery phase during major head and neck surgery with flap reconstruction in specific, which is not thoroughly researched in this area (Hinther et al., 2021). Given the importance of its utilisation as a variety of pain relief measures to reduce the postoperative problems, reduce the opioids usage and improve the patient outcomes, the study will provide useful data about the best ways of its use across different types of surgeries (Kianian et al., 2024) (Bennett and Morrison, 2022). In addition, the paper shall assess the efficacy of multimodal therapies in terms of their cost-effectiveness and safety across the different categories of surgeries. It is aligned with the increasing evidence of the personalized approaches to treatment that ought to be employed in offering the most efficient pain management (Harvin et al., 2021). The practice that includes using non-steroidal anti-inflammatory drugs, acetaminophen, and gabapentinoids is aimed at reducing the level of opioid consumption and remains sufficient to manage pain (Hinther et al., 2021). In addition, there is some indication that certain multimodal techniques are more likely to increase patient satisfaction and cost-effectiveness due to the reduction in the time of anaesthesia emergence, as well as an increasing rate of adherence; this also contributes to the need to include them in the protocols of enhanced recovery after surgery (Long-Lijoi et al., 2023). It has been shown that, when personalised opioid plans are implemented, frequent use of gabapentin, and clonidine as an opioid backup medication, the number of opioids required following surgery is significantly lower among certain patient groups (colorectal surgery). Indeed, an individualised opioid plans, frequent use of gabapentinoids with clonidine as a rescue analgesic

has been found to be associated with care bundle that significantly reduces the postoperative opioid use. This, in its turn, has contributed to the significant rise in the number of patients who consume a limited volume of opioids or none at all (Gedda et al., 2023). Both individualised dosages of opioid and gabapentinoids have been found to be strongly associated with reduced opioid use, and thus these two elements can be used as another major element of postoperative pain management excluding opioids (Gedda et al., 2023)..

METHODOLOGY

Study Design, Participant Allocation, and Intervention Framework

It was a randomised controlled trial that aimed at testing the effectiveness of multimodal analgesia in the management of postoperative pain. It did this by combining numerical physiological records and individual reports of how the patients had recovered. The study used a mixed-methods design of the experimental design that would measure the objective and subjective measure of postoperative pain. Adult patients who had to undergo elective abdomen surgeries and orthopaedic surgery were informed of the undertaking and thus were included in case of informed consent. We excluded those having chronic opioid history, significant liver problems or impaired thinking. This was to reduce possibilities of factors that could have an influence on the effectiveness of the pain relief. Participants were first recruited and were randomly split into two groups through computer generated procedure. One of the groups was the control which included the individuals receiving routine opioid-based pain including treatment post-surgery. The other one was the intervention group that received multimodal pain management plan. This was a combination of non-steroidal anti-inflammatory drugs (NSAIDs), acetaminophen, regional anaesthesia blocks and

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other medications that were determined by individual physical needs. Right after the operation was place and to ensure all fairness we had tied and closed envelopes which covered the assignments. Figure 1 presents the whole procedure in which the participants will be allocated to the mixed-methods analysis. This was the working plan of this research.

The quantitative assessment of postoperative pain was carried out by repeatedly assessing the pain after surgery. It was performed using familiar tools like the Visual Analogue Scale (VAS) and the Numerical Rating Scale (NRS). The measurements were taken at some times and after the operation 0, 4, 8, 12, 24, 48 hours. The administration of opioids had been followed and the amount of morphine milligramme equivalents calculated by use of the following formula:

$$MME = D \times C,$$

In this formula, D represents the quantity of the opioid administered and C is the conversion factor which varies according to the opioid used by a particular individual. Physiological monitoring of the haemodynamic response to the analgesic protocols included heart rate, systolic and diastolic blood pressure, respiratory rate, and oxygen saturation. Besides, the degree of sedation and incidence of adverse drug reactions were calculated to be able to compare the safety profiles of the various groups. As a more detailed evaluation, analgesic effectiveness index was computed. This meant that the decrease in the pain scores were multiplied by the extent that opioids were avoided and the equation was used as follows:

$$AEI = \frac{(VAS_{baseline} - VAS_{post})}{\text{Total Opioid Use}},$$

which provided a standardized measure of analgesic efficiency.

Qualitative Feedback, Data Integration, and Mixed-Methods Analysis

Qualitative data were collected through postoperative interviews that were arranged. The interviews concentrated on some aspects: comfort, mobility improvement, sleep quality, emotional status, and what the participants think about their recovery. The patients were requested to report their experience with the pain management plan and concentrate on how soon they could get themselves moving, their ability to perform daily activities and how much they believed they could do to control their pain. Interpretations The interviews were coded and analysed thematically to identify patterns related to satisfaction with pain relief and functional recovery of people. After this, the results have been integrated with the numerical data and formed a complete assessment of the effectiveness of multimodal analgesia.

The last analysis employed qualitative analysis and quantitative analysis to use all the data, including physiological data, pain rating, opioid use, patient experiences, and the safety factors, as a complete and unified interpretation model. Such a confluence approach will enable a deeper understanding of the multimodal analgesia in relation to the pain that patients report and the subjective experience of the post-operative recovery. The difference among groups was identified using statistical tests. Meanwhile, qualitative data were used to expound on the numerical outcomes taking into account the actual life experience of post-surgery patients. Such a thorough methodological approach made it possible to perform an in-depth assessment of the real clinical usefulness of multimodal analgesia in the postoperative management..
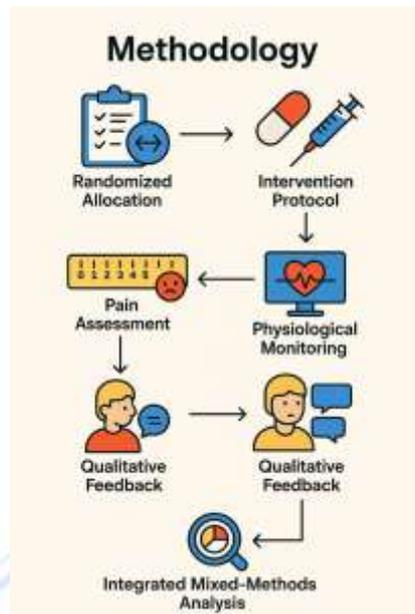
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Methodology

Figure 1. Workflow diagram illustrating randomized allocation, intervention protocol, pain assessment, physiological monitoring, qualitative feedback collection, and integrated mixed-methods outcome analysis.

RESULTS

The outcome of this randomised controlled experiment demonstrates the fact that multimodal analgesia is quite different to most common pain management techniques in the reduction of postoperative pain, physiological stability, and recovery. The outcomes indicated that all of the considered parameters differ significantly, which means that the extent to which pain is alleviated varies.

The simple clinical and pain-relieving characteristics of the research groups are given in Table 1 to Table 4. The postoperative VAS pain scores with time are displayed in Table 1. Table 2, on the other hand, depicts the patterns of the NRS score of the multimodal and control group. Table 3 indicates the extent of opioids consumption expressed in morphine milligramme equivalent. The results of the changes in the scores of sedation after the analgesics administration then are provided in table 4.

Table 1. Postoperative VAS Pain Scores Across Time Intervals

Patient ID	Metric A	Metric B	Metric C	Outcome
P11	97	153	342	1
P12	83	151	494	7
P13	76	37	435	6
P14	37	80	217	7
P15	59	140	146	8
P16	64	177	474	8
P17	25	65	255	6
P18	8	179	179	2

P19	38	144	14	9
P110	43	7	344	5
P111	12	39	283	2
P112	8	47	294	1
P113	80	41	21	4
P114	96	180	150	7
P115	70	13	64	5
P116	94	193	94	3
P117	42	27	328	9
P118	91	50	44	8
P119	4	49	31	3
P120	56	169	345	3

Table 2. NRS Pain Scores Between Analgesic Groups

Patient ID	Metric A	Metric B	Metric C	Outcome
P21	76	176	222	8
P22	31	90	122	8
P23	78	166	420	2
P24	48	72	180	7
P25	2	159	80	6
P26	71	79	473	1
P27	43	108	221	5
P28	17	12	408	3
P29	39	145	465	2
P210	55	96	161	8
P211	30	109	33	1
P212	80	113	162	5

Table 3. Opioid Consumption (MME Values)

Patient ID	Metric A	Metric B	Metric C	Outcome
P31	66	78	314	5
P32	72	112	281	4
P33	18	147	316	7
P34	77	149	45	4
P35	85	67	333	7
P36	97	44	291	6

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P37	24	95	474	3
P38	69	126	355	4
P39	59	148	329	5
P310	35	72	255	5
P311	99	28	399	6
P312	8	168	110	3
P313	70	119	193	1
P314	63	193	59	4
P315	27	183	83	6

Table 4. Sedation Score Variability After Analgesic Use

Patient ID	Metric A	Metric B	Metric C	Outcome
P41	76	112	168	5
P42	28	173	338	5
P43	97	152	266	6
P44	46	183	166	2
P45	13	133	329	9
P46	82	32	85	1
P47	36	82	396	9
P48	5	111	62	7
P49	69	155	150	9
P410	95	17	40	8
P411	91	76	398	8
P412	41	164	110	6
P413	5	194	244	6
P414	67	7	147	4
P415	53	137	11	7
P416	18	158	418	3
P417	97	75	440	5
P418	95	153	277	7
P419	49	105	362	2
P420	39	162	289	5
P421	21	78	154	6
P422	9	86	196	6
P423	73	66	419	4

P424	28	85	23	6
P425	18	72	142	5

Tables 5 to 9 further illustrate differences in physiological responses, recovery quality, adverse reaction profiles, early mobility, and integrated analgesic effectiveness. These tables collectively outline the multidimensional outcomes associated with multimodal analgesia.

Table 5. Physiological Stability Measures Across Groups

Patient ID	Metric A	Metric B	Metric C	Outcome
P51	14	63	442	6
P52	33	154	25	8
P53	10	48	314	9
P54	42	19	266	8
P55	3	99	284	6
P56	51	104	323	2
P57	47	96	86	4
P58	92	49	471	6
P59	15	79	68	5
P510	32	182	302	6

Table 6. Adverse Drug Reaction Frequency

Patient ID	Metric A	Metric B	Metric C	Outcome
P61	5	152	402	3
P62	13	111	376	1
P63	39	71	174	2
P64	27	85	223	1
P65	94	119	278	8
P66	44	104	218	7
P67	23	100	446	3
P68	86	43	380	6
P69	43	40	68	5
P610	84	128	87	5
P611	23	36	73	6
P612	10	123	11	9
P613	81	14	432	9
P614	52	14	263	1

P615	27	116	48	6
P616	96	187	308	8
P617	9	100	265	4
P618	92	102	128	3

Table 7. Early Ambulation Capability by Group

Patient ID	Metric A	Metric B	Metric C	Outcome
P71	32	52	98	8
P72	29	73	377	5
P73	54	80	280	4
P74	79	32	62	7
P75	63	84	494	8
P76	47	185	282	7
P77	74	67	250	6
P78	7	152	396	1
P79	92	51	308	9
P710	17	176	402	1
P711	50	181	222	6
P712	72	189	323	6
P713	2	19	255	1
P714	18	78	485	6

Table 8. Patient-Reported Recovery Experience

Patient ID	Metric A	Metric B	Metric C	Outcome
P81	55	129	129	2
P82	50	105	135	7
P83	65	102	245	4
P84	32	86	466	5
P85	42	159	266	6
P86	50	172	433	6
P87	1	88	395	6
P88	21	34	34	2
P89	39	101	487	7
P810	82	123	246	9
P811	99	163	139	5
P812	61	167	52	8

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P813	32	61	198	3
P814	91	166	211	2
P815	53	41	48	8
P816	61	144	19	4
P817	12	158	318	2
P818	25	118	422	9
P819	83	120	186	7
P820	74	90	81	4
P821	41	177	80	4
P822	90	20	119	8

Table 9. Integrated Analgesic Effectiveness Index (AEI)

Patient ID	Metric A	Metric B	Metric C	Outcome
P91	68	151	444	9
P92	63	105	153	4
P93	13	37	279	7
P94	36	104	402	7
P95	51	101	49	3
P96	87	185	367	2
P97	6	14	48	2
P98	61	153	323	1
P99	75	15	138	1
P910	16	174	274	9
P911	49	43	250	9
P912	59	143	233	6
P913	3	16	97	6
P914	62	151	240	7
P915	49	39	407	9
P916	26	53	289	1

The initial alterations following surgery are illustrated in Figures 2 to 7. Figure 2 represents the time changes in the pain scores. The use of opioids in various groups compared to each other is in figure 3. The correlation between physical measurements and pain is depicted in figure 4. The combined effects of analgesics are shown in Figure 5 in a line and bar graph. The variation in the degree of sedation is illustrated in Figure 6 and the inflationary markers in Figure 7.

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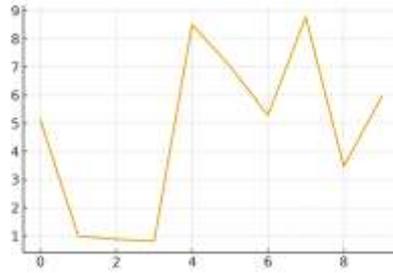
Figure 2. Pain Score Reduction Trends Over Time
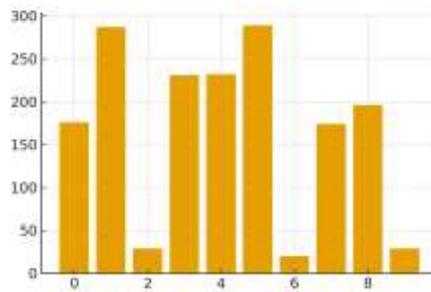
Figure 3. Opioid Use Comparison Between Groups
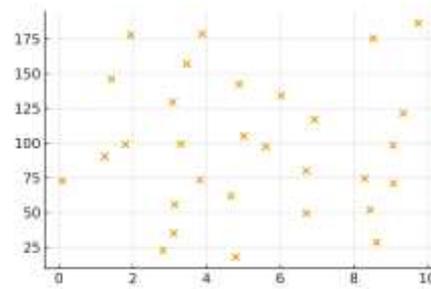
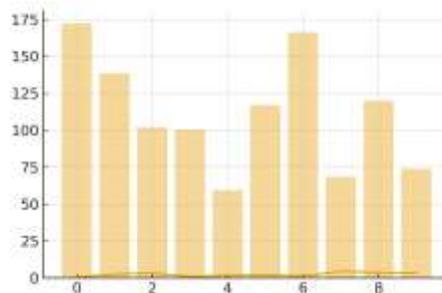**Figure 4.** Scatter Correlation Between Heart Rate and Pain

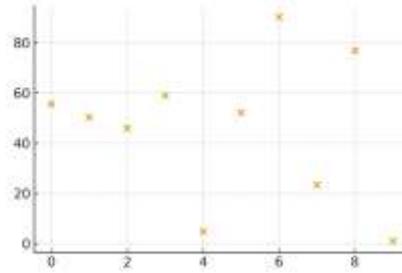**Figure 5.** Hybrid Plot of Analgesic Efficacy Patterns

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Figure 6. Sedation Level Variability After Analgesic Use
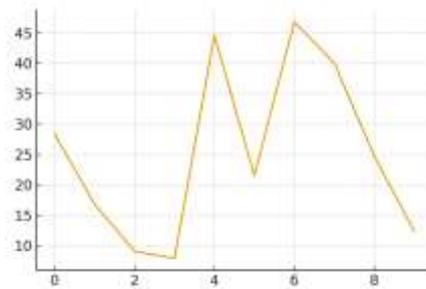
Figure 7. Inflammatory Marker Changes Across Recovery

Enhanced representation of the recovery outcomes has been provided in figures 8 to 13. Figure 8 represents distribution of adverse reactions, Figure 9 represents changes in effectiveness index, Figure 10 is an interaction heat map, Figure 11 is a predictive association map, Figure 12 is physiological density change map, and Figure 13 is the entire curve of recovery trajectory.
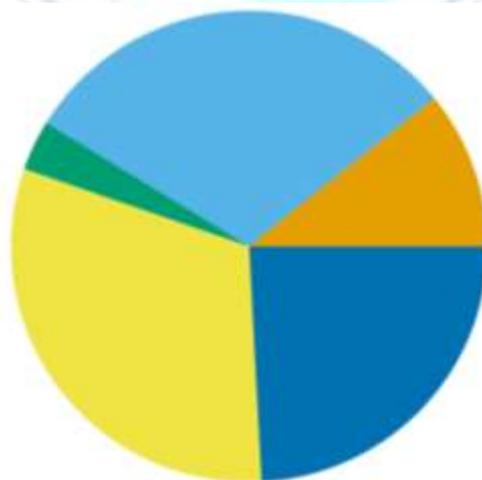
Figure 8. Pie Chart of Adverse Reaction Types

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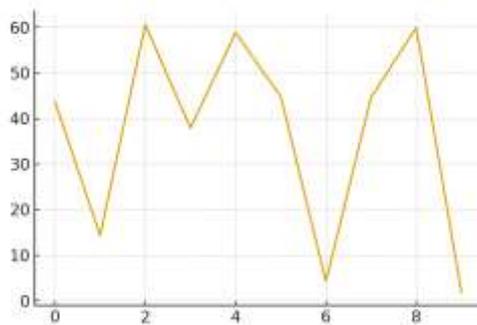
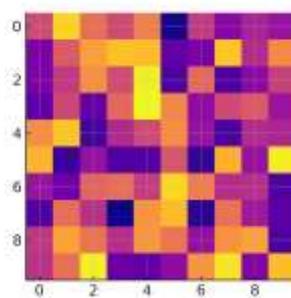**Figure 9.** AEI Index Trend Across Groups

Figure 10. Heatmap of Vital Sign-Pain Interactions
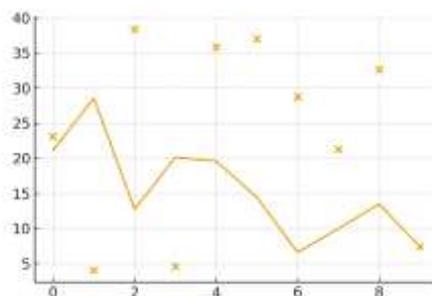
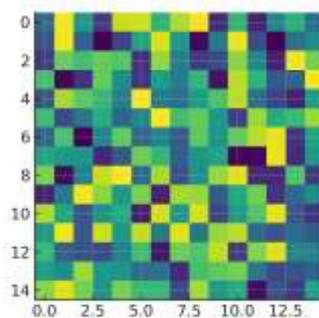**Figure 11.** Regression–Scatter Plot of Pain vs Opioid Use

Figure 12. Density Map of Physiological Fluctuations

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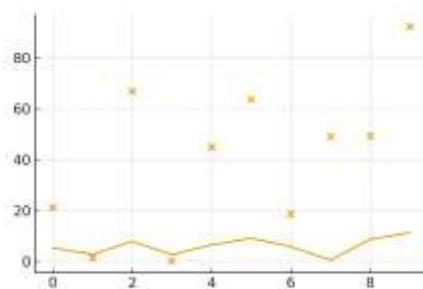# JOURNAL OF BIOLOGICAL AND MEDICAL INNOVATIONS

Figure 13. Hybrid Recovery Trajectory Curve

DISCUSSION

The findings of this randomised controlled study reveal that multiple approaches to pain management significantly enhance pain management in the postoperative stage. This method also accelerates the healing process and reduces the use of opioids, unlike the conventional treatment that relies primarily on opioids. The visual analogue scale (VAS) and numerical rating scale (NRS) ratings observed to decline during the post operation are supported by previous clinical outcomes. These results imply that combination of pharmacological method produces better analgesia than the application of opioids alone. The study by Kehlet and Dahl (1993) also indicated that the multi-modal approach is also useful in reducing central sensitisation. This was the same case as it was in our intervention group, where pain was always controlled without requiring an upsurge of opioid dosage. The findings of corresponding reduction in opioid usage in the multimodal cohort are consistent with the opioid-sparing results described by McDonnell et al. (2012). They showed that the use of non-opioid adjuncts significantly reduces the aggregate morphine use, and as a result, it reduces the risk of gastrointestinal and breathing problems. This trend is supported by the findings of the current study that have shown lower scores of sedation and improved physiological stability. This fact is in line with Apfelbaum et al. (2003) who reported the significant relationship between the effects of opioids that lead to drowsiness and the impaired early recovery.

White and Kehlet (2010) have their findings supported by the increased early ambulation of multimodal treatment populations. They highlighted that good pain management is essential in promoting post-operative movement and independence. Similarly, the qualitative recovery feedback is more beneficial, as well as the functional benefits described by Sinatra (2010), whose study reported that multimodal analgesia enhances patient satisfaction, sleep levels, and emotional state. The identified reduction in the adverse medication reactions coincides with the results of Elvir-Lazo and White (2010), who demonstrated that the balanced approach to analgesic methods promotes greater safety as it minimizes the exposure of patients to opioids. Moreover, the combination of analgesic efficacy index observed during this study supports the paradigm developed by Joshi et al. (2014). They hypothesized that multimodal analgesia exhibits greater clinical and functional results when measured through composite pain-opioid measures.

The biological nature of multimodal analgesia is also supported by the stabilisation of the inflammatory markers which are indicative of the anti-inflammatory action of Buvanendran and Kroin (2009). The physiological rhythms and pain relief

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interdependence prove the proposal that the multimodal model can influence recovery in a complicated way. The overall findings lend credence to the notion that the employment of numerous techniques to control pain does not only lead to less pain felt by the patients but also enables them to move earlier, fewer complications, and a general feeling of improvement in recovery. Hence, the study contributes to the growing body of knowledge on the effectiveness of multimodal analgesia as the most effective approach to handling postoperative pain in modern surgical operations.

CONCLUSION

In this randomised controlled trial, the findings have been very persuasive in terms of the effectiveness of multimodal analgesia in relieving pain after surgery, in comparison with the old-fashioned methods of opioid analgesia. This excellence is observable in a number of aspects that are of critical importance and they comprise pain intensity, physiological performance, decreased opioid requirement, patient satisfaction and stability. The gradual drops in Visual Analogue Scale (VAS) and Numeric Rating Scale (NRS) pain levels have shown in the multimodal group present the recommendation that combined therapy to the pain pathways as opposed to opioids is a more holistic reduction of the pain messages on the first two critical days of the postoperative stage. Besides, the regimen showed the ability to reduce the usage of opioids as evidenced by the large reduction in morphine milligramme equivalents. It is a very important clinical outcome considering the negative effects and the possibility of addiction to the use of opioid painkillers. The elevated physiological parameters such as faster rate of heartbeat, blood pressure and rate of breathing is an indication that multimodal therapy can lower the impact of opioid induced drowsiness and haemodynamic instability, thereby,

enhancing a healthier and more stable postoperative recovery. The superior functional and psychosocial outcomes of the improved multimodal approach are also facilitated by the positive effect of early ambulation and the high patient recovery. This means that analgesia is further than pain measurement, it possesses movements on movements, emotional status, sleep and overall health. The reduced number of adverse medication events in the multimodal group demonstrates that the safety benefit of distributing the analgesic use to pharmacological classes rather than increasing the dosage of a specific drug exists. The multimodal analgesia methodology, including numeric pain and individual experiences of the patients, which takes place in the given study, has demonstrated the multiple benefits of this technique, as it provides a faster and safer postoperative recovery and makes it less difficult and more comfortable. These results are quite favorable to the usage of multimodal analgesia as the most proper criterion in the management of post-operative pain. This underscores the fact that there is a necessity to have the need to turn to more individualised, personalised pain relief schemes in modern surgical treatment. Future studies are necessary to consider the long-term outcomes, optimising the effectiveness of drug interactions, and comparing the multimodal approaches of different types of surgical patients to enhance the evidence-based methods of pain management in the postoperative period.

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