

Impact of Moderate vs Deep Neuromuscular Blockade on Acute and Chronic Postoperative Pain in Laparoscopic Inguinal Hernia Surgery: A Multicenter Retrospective Randomized Controlled Trial

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ABSTRACT

Background and aim of the study: Significant postoperative discomfort is linked to laparoscopic inguinal hernia repair, and in certain patients, this pain may develop into chronic pain. Intraoperative neuromuscular blockade (NMB) depth may have an impact on surgical circumstances and the course of postoperative pain. The effects of deep vs mild NMB on immediate and long-term postoperative pain in patients having laparoscopic inguinal hernia repair were examined in this study.

Materials and Methods: Between July 2024 and July 2025, 85 patients undergoing laparoscopic inguinal hernia repair at related centers participated in this multicenter retrospective randomized controlled trial. Patients were assigned to either mild NMB (Group B, n = 41) or deep NMB (Group A, n = 44). Visual Analog Scale (VAS) pain scores at 0.5, 2, 4, 6, and 24 hours after surgery as well as chronic postoperative pain (CPSP) at 3 and 6 months were the main results. Perioperative opioid use, rocuronium dosage, sugammadex needs, extubation duration, and adverse events were secondary outcomes.

Results: Demographic and surgical characteristics were comparable between groups. Group A demonstrated significantly lower VAS scores at 0.5 hours (5.2 ± 1.1 vs. 6.1 ± 1.3 , $p < 0.05$), 2 hours (4.1 ± 1.0 vs. 5.3 ± 1.2 , $p < 0.05$), and 4 hours (3.2 ± 0.9 vs. 4.2 ± 1.1 , $p < 0.05$). CPSP at 3 months was lower in Group A (2.27% vs. 9.76%, $p = 0.341$), with no pain reported at 6 months in either group. Postoperative morphine requirements were significantly reduced in Group A (8.2 ± 2.5 mg vs. 14.6 ± 3.8 mg, $p = 0.011$), and rescue analgesia was required less

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frequently (22.7% vs. 48.8%, $p=0.019$). Group A received higher rocuronium doses (85.4 ± 12.3 mg vs. 52.1 ± 10.5 mg, $p=0.002$) and more frequent sugammadex reversal (93.2% vs. 63.4%, $p=0.001$), but extubation times were comparable ($p=0.148$). Adverse event rates were similar between groups.

Conclusion: Without sacrificing patient safety or delaying recovery, deep neuromuscular blockade during laparoscopic inguinal hernia repair is linked to markedly better early postoperative pain control, fewer opioid requirements, and a clinically significant trend toward lower chronic pain incidence. The integration of deep NMB into improved recovery regimens for laparoscopic hernia repair is supported by these results.

Keywords: neuromuscular blockade, laparoscopic inguinal hernia repair, postoperative pain, chronic pain, opioid consumption, sugammadex

INTRODUCTION

Laparoscopic inguinal hernia repair has become the acknowledged standard of care since it is associated with less postoperative pain, a faster recovery, and an earlier return to work than open procedures (1,2). Patients frequently have severe postoperative pain, which can be temporary or, in certain situations, develop into chronic, crippling discomfort, despite these minimally invasive advantages (3). After inguinal hernia repair, up to 10–20% of patients have chronic post-surgical pain (CPSP), which significantly lowers quality of life (4).

To improve surgical circumstances and ease tracheal intubation, intraoperative neuromuscular blocking (NMB) is frequently utilized. Deep NMB has been demonstrated to enhance the surgical workspace during laparoscopy, especially in cramped areas, by relaxing the abdominal muscles (5,6). Theoretically, this improved visibility could prevent tissue damage from instrument manipulation and lessen the requirement for high intra-abdominal insufflation pressures (7). Although deep NMB has been shown to improve surgical circumstances, its direct effect on patient-centered outcomes, particularly pain, is still being researched.

The effects of deep vs mild NMB on immediate postoperative pain scores and opioid use have been the main focus of previous research, with mixed results (8, 9). However, nothing is known about the connection between the degree of intraoperative muscle relaxation and the emergence of persistent, long-term discomfort. It is conceivable that deep NMB's enhanced surgical field and less tissue damage could lessen the frequency of inflammatory reactions and nerve irritation, two major factors in chronic pain pathways (10). The long-term impact of NMB depth on acute and chronic pain outcomes after laparoscopic inguinal surgery has not been thoroughly examined in many studies to date.

Comparing the effects of deep vs mild neuromuscular blockade on postoperative pain in patients following laparoscopic inguinal hernia repair was the main goal of this retrospective, randomized controlled research. In comparison to mild NMB, we predicted that deep NMB would be linked to lower immediate postoperative pain scores and a decreased incidence of chronic post-surgical pain at three and six months postoperatively.

MATERIALS AND METHODS

Research Framework and Environment

In order to evaluate the effects of deep versus mild neuromuscular blockade on postoperative pain outcomes in patients undergoing laparoscopic inguinal hernia repair, this multicenter, retrospective, randomized controlled study was conducted. Over the course of a year, from July 2024 to July 2025, the study was carried out in the Department of Surgery in collaboration with four related surgical centers. The study's methodology was approved by the Institutional Review Board (IRB), and because the data analysis was retrospective, informed permission was not required.

Patient Selection and Randomization

The final analysis included 85 individuals who received elective laparoscopic inguinal hernia repair during the research period. Patients were assigned to one of two groups according to the extent of neuromuscular blockade delivered during the operation: the Deep Neuromuscular Blockade group (Group A, $n = 44$) and the Moderate Neuromuscular Blockade group (Group B, $n = 41$). The allocation was created by examining the intraoperative anesthetic records, where the selection of blockade depth was randomly given based on a pre-determined computer-generated randomization list at the time of surgery.

Inclusion and Exclusion Criteria

The inclusion criteria were: (1) adult patients between the ages of 18 and 65; (2) those in physical status I or II according to the American Society of Anesthesiologists (ASA); (3) those slated for elective laparoscopic inguinal hernia repair; and (4) availability of complete medical records for examination. The exclusion criteria comprised: (1) a history of chronic pain or prolonged opioid usage, (2) conversion to open surgery, (3) allergy to neuromuscular blocking drugs, and (4) absence of follow-up data at 3 or 6 months post-operatively.

Intraoperative Administration

All patients received general anesthesia accompanied by endotracheal intubation. Neuromuscular blockage was assessed with train-of-four (TOF) acceleromyography. In Group A (Deep NMB), patients were administered rocuronium boluses adjusted to sustain a post-tetanic count (PTC) of 1–2, indicative of deep neuromuscular blockade. In Group B (Moderate NMB), the blockade was sustained at a TOF count of 1–2. Neuromuscular inhibition was reversed with sugammadex in both groups at the end of the procedure.

All surgical procedures were conducted utilizing a standardized laparoscopic transabdominal preperitoneal (TAPP) or completely extraperitoneal (TEP) technique, contingent upon the surgeon's preference and the patient's anatomical considerations. Intra-abdominal pressure was sustained within the range of 10–12 mmHg. Information concerning hernia classification (indirect, direct, or mixed) and laterality (unilateral or bilateral) was extracted from operating records to guarantee comparison among groups.

Data Acquisition and Result Metrics

Demographic and baseline information, such as age, body mass index (BMI), and ASA categorization, were obtained from electronic medical records. Perioperative data, including surgery duration and hernia characteristics, were documented.

The principal endpoint of this study was postoperative pain, evaluated across two domains:

Acute Postoperative Pain

Visual Analog Scale (VAS) values were documented at 0.5, 2, 4, 6, and 24 hours following surgery.

Chronic Postoperative Pain

Chronic postoperative pain (CPSP) is characterized by enduring pain at the surgical site that persists for over 3 months following surgery, as per the guidelines of the International Association for the Study of Pain (IASP). Data on CPSP were gathered at 3 and 6 months postoperatively via standardized telephone interviews or during usual outpatient clinic follow-up visits.

Secondary Outcomes Comprised:

- Total intraoperative dosage of rocuronium;
- Status of Sugammadex administration;
- Duration of extubation;
- Morphine comparable doses during and after surgery;
- Frequency of supplementary analgesic use post-operatively;
- Postoperative complications (pharyngodynia, nausea and emesis, vertigo, pruritus, urine retention).

Statistical Analysis

SPSS software (version 26.0, IBM Corp., Armonk, NY, USA) was used for statistical analysis. The mean $\pm$ standard deviation was used to express continuous variables such as age, BMI, and length of surgery. An independent samples t-test was used to compare groups for these variables, and the resulting statistic was called "t".

Counts and percentages were used to report categorical parameters, including ASA classification, hernia type, surgery laterality, incidence of CPSP, and postoperative complications. The Chi-square test (χ^2) or, when appropriate, Fisher's exact test were used to compare Group A and Group B for these categorical outcomes (e.g., when projected cell counts were below 5).

For overall comparisons, repeated-measures analysis of variance (ANOVA) was used to analyze VAS pain scores across time. Post-hoc independent samples t-tests were then used to assess differences between the two groups at each particular time point.

The Mann-Whitney U test (Z statistic) was used to assess the non-normal distribution of the extubation time, which was reported as the median with interquartile range.

In instances where no events transpired in either group (e.g., CPSP at 6 months and pruritus), statistical

analysis was classified as "Not Applicable" (NA), as a proper comparison could not be conducted.

A p-value below 0.05 was deemed statistically significant.

RESULTS

Surgical Data and Patient Features

85 individuals who had laparoscopic inguinal hernia surgery between July 2024 and July 2025 were included in this retrospective, randomized controlled study. Patients were split into two groups based on the level

of neuromuscular blockade: Group A (Deep Neuromuscular Blockade, $n = 44$) and Group B (Moderate Neuromuscular Blockade, $n = 41$). The CONSORT flow diagram, which illustrates patient recruitment and randomization, is shown in *fig. 1*.

Table 1 summarizes the clinical and demographic features of the two groups, which were similar. Group A and Group B had mean ages of 42.5 ± 9.1 and 43.2 ± 9.7 years, respectively ($p = 0.732$). Between the groups, the body mass index (BMI) was comparable (24.1 ± 2.5 kg/m² vs. 23.0 ± 2.8 kg/m², $p = 0.114$). There was no discernible variation in the ASA distribution ($p = 0.643$), with the majority of patients in both groups (Group A: 35 patients, Group B: 34 patients) being categorized as ASA I.

The distribution of hernia types was similar between groups in terms of hernia features ($p = 0.539$). In Group A, 15 patients (34.1%) had mixed (pantaloon) hernias, 13 (29.5%) had direct hernias, and 16 patients (36.4%) had indirect inguinal hernias. Of the patients in Group B, 11 (26.8%) had mixed hernias, 17 (41.5%) had direct hernias, and 13 (31.7%) had indirect hernias. The majority of operations were performed unilaterally (Group A: 90.9%, Group B: 95.1%), and the distribution of laterality did not differ significantly ($p = 0.615$). Group A and Group B experienced similar surgical durations, with an average of 112.5 ± 38.5 and 122.1 ± 43.8 minutes, respectively ($p = 0.323$).

Postoperative Pain Outcomes

VAS scores for acute postoperative pain

The Visual Analog Scale (VAS) pain scores following surgery are shown in *fig. 2* at five different time points:

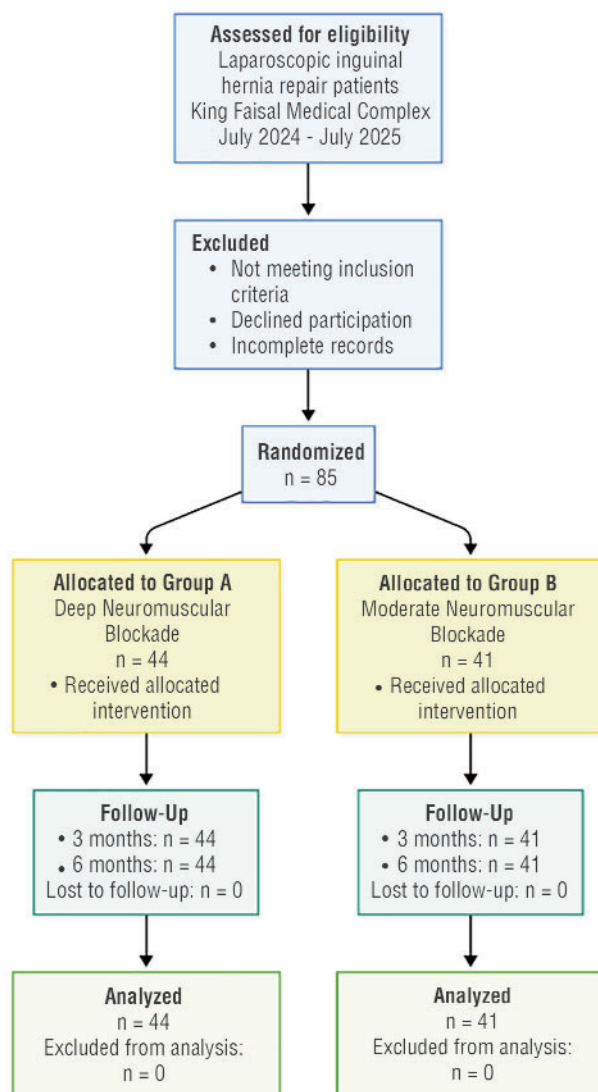


Figure 1 - CONSORT Flow Diagram for Randomization and Patient Recruitment. Flow diagram showing how patients were chosen and assigned for laparoscopic inguinal hernia surgery at King Faisal Medical Complex between July 2024 and July 2025. There were 85 patients in all, 44 of them were assigned to Group A (Deep NMB) and 41 to Group B (Moderate NMB).

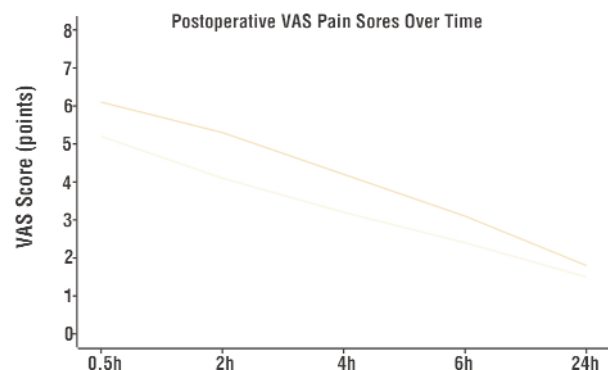


Figure 2 - Pain scores on the Visual Analog Scale (VAS) following surgery at different times. VAS scores at 0.5, 2, 4, 6, and 24 hours after surgery were compared between Group A (Deep NMB, solid blue line) and Group B (Moderate NMB, dashed orange line). * indicates $p < 0.05$; data are shown as mean $\pm$ SD.

Table 1 - Demographic Characteristics and Surgery-Related Data

Index	Group A (Deep NMB)	Group B (Moderate NMB)	Statistic	p value
Age (years)	42.5 ± 9.1	43.2 ± 9.7	t = 0.343	0.732
BMI (kg/m ²)	24.1 ± 2.5	23.0 ± 2.8	t = 1.602	0.114
ASA classification (I/II)	35 / 9	34 / 7	$\chi^2 = 0.214$	0.643
Hernia Type n (%)			$\chi^2 = 1.237$	0.539
Indirect	16 (36.4%)	13 (31.7%)		
Direct	13 (29.5%)	17 (41.5%)		
Combined / Pantaloon	15 (34.1%)	11 (26.8%)		
Surgery Laterality n (%)			$\chi^2 = 0.880$	0.615
Unilateral	40 (90.9%)	39 (95.1%)		
Bilateral	4 (9.1%)	2 (4.9%)		
Surgical duration (min)	112.5 ± 38.5	122.1 ± 43.8	t = 0.995	0.323

*Data presented as mean ± SD or n (%). Group A: Deep NMB (n=44); Group B: Moderate NMB (n=41).

Comparisons: t-test for continuous variables, χ^2 test for categorical variables. BMI: Body Mass Index;

ASA: American Society of Anesthesiologists. All baseline characteristics were comparable between groups (p > 0.05).*

0.5, 2, 4, 6, and 24 hours after surgery. At every time point, patients in Group A (Deep NMB) continuously reported lower pain scores than those in Group B (Moderate NMB). At 0.5 hours (Group A: 5.2 ± 1.1 vs. Group B: 6.1 ± 1.3, p < 0.05), 2 hours (Group A: 4.1 ± 1.0 vs. Group B: 5.3 ± 1.2, p < 0.05), and 4 hours after surgery (Group A: 3.2 ± 0.9 vs. Group B: 4.2 ± 1.1, p < 0.05), statistically significant differences were seen. At 6 hours (2.4 ± 0.8 vs. 3.1 ± 0.9) and 24 hours (1.5 ± 0.6 vs. 1.8 ± 0.7), Group A's mean VAS ratings were still lower, but they were not statistically significant (p = 0.07 and p = 0.21, respectively).

CPSP, or chronic postoperative pain

Table 2 shows the prevalence of persistent postoperative pain at three and six months after surgery. Compared to four patients (9.76%) in Group B, just one patient (2.27%) in Group A had ongoing groin discomfort three months after surgery. The difference did not achieve statistical significance ($\chi^2 = 1.274$, p = 0.341), despite the fact that this indicates a lower incidence in the deep NMB group. No patients in either group reported persistent pain at 6 months after surgery (0% in both groups), and as there were no events, statistical analysis was not possible.

Intraoperative Neuromuscular Blockade Profile

The profile of intraoperative neuromuscular inhibition is shown in *fig. 3*. As anticipated, Group A patients were given a substantially greater dosage of total rocuronium than Group B patients (85.4 ± 12.3 mg vs. 52.1 ± 10.5 mg, t = 3.30, p = 0.002) (*fig. 3 a*).

41 patients (93.2%) in Group A and 26 patients (63.4%) in Group B needed sugammadex medication (*fig. 3 b*), a statistically significant difference ($\chi^2 = 4.256$, p = 0.001). This indicates that deeper neuro-muscular inhibition has to be actively reversed.

Extubation time (*fig. 3 c*) was similar across groups, despite variations in rocuronium dosage and reversal needs. There was no discernible difference between Group A and Group B's median extubation times, which were 8.5 minutes (IQR: 6.2-11.4) and 7.8 minutes (IQR: 5.9-10.2), respectively (Z = -1.446, p = 0.148).

Use of opioids during surgery and needs for analgesics

Perioperative opioid use and analgesic needs are shown in *fig. 4*. Group A and Group B had comparable intraoperative morphine equivalent doses

Table 2 - Chronic Postoperative Pain (CPSP) at 3 and 6 Months Postoperatively

Index	Group A (Deep NMB)	Group B (Moderate NMB)	Statistic	p value
CPSP at 3 months postoperatively (n, %)	1 (2.27%)	4 (9.76%)	$\chi^2 = 1.274$	0.341
CPSP at 6 months postoperatively (n, %)	0 (0.00%)	0 (0.00%)	NA	NA

*Counts (percentages) are used to display the data. The International Association for the Study of Pain (IASP) standards defined CPSP as chronic pain at the surgical site that persisted for more than three months after surgery. The chi-square test was used to compare groups. "NA" stands for "Not Applicable" because there were no incidents in either group at the six-month mark, making statistical analysis impossible. Group A showed a 77% relative decrease in CPSP incidence at three months after surgery compared to Group B (2.27% vs. 9.76%), however this difference was not statistically significant (p = 0.341).

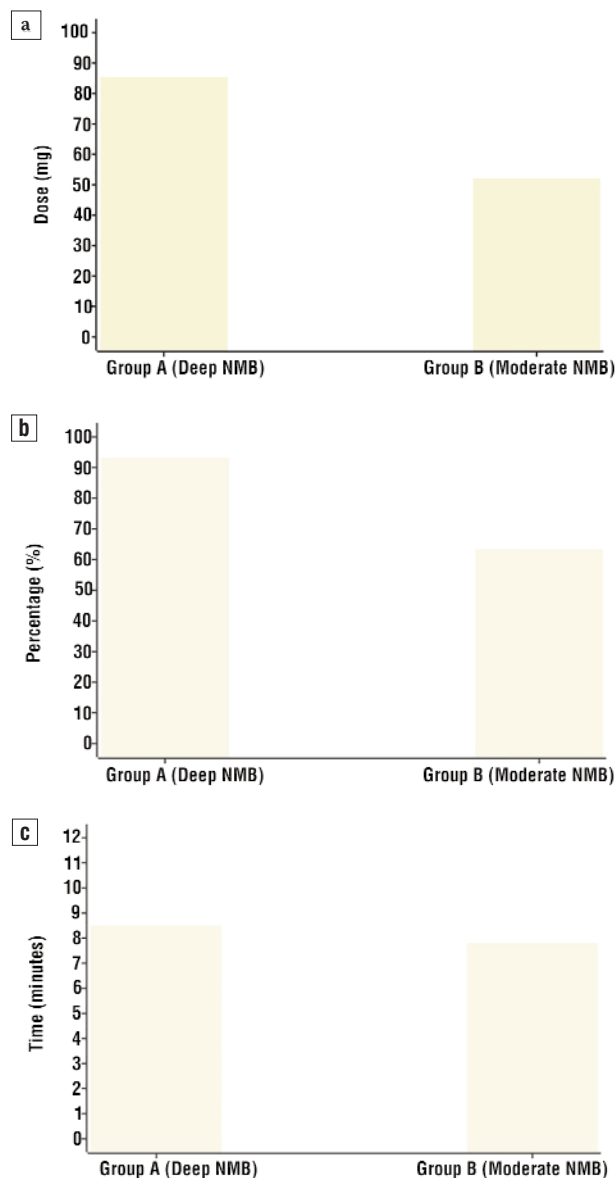


Figure 3 - Intraoperative Neuromuscular Blockade Profile. (a) Total rocuronium dose (mean $\pm$ SD); (b) Sugammadex administration status; (c) Extubation time (median with IQR). Blue bars represent Group A (Deep NMB), orange bars represent Group B (Moderate NMB). * denotes $p < 0.05$.

(fig. 4 a), with Group A getting 18.5 ± 4.2 mg and Group B receiving 19.2 ± 4.8 mg ($t = 1.00$, $p = 0.321$).

Comparing Group A to Group B, however, the postoperative morphine equivalent doses (fig. 4 b) were considerably lower (8.2 ± 2.5 mg vs. 14.6 ± 3.8 mg, $t = 2.63$, $p = 0.011$). This indicates that individuals who had profound neuromuscular blockade had a 43.8% lower need for opioids after surgery.

In line with this conclusion, Group A saw a considerably reduced incidence of postoperative extra analgesic administration (fig. 4 c), with only 10 patients

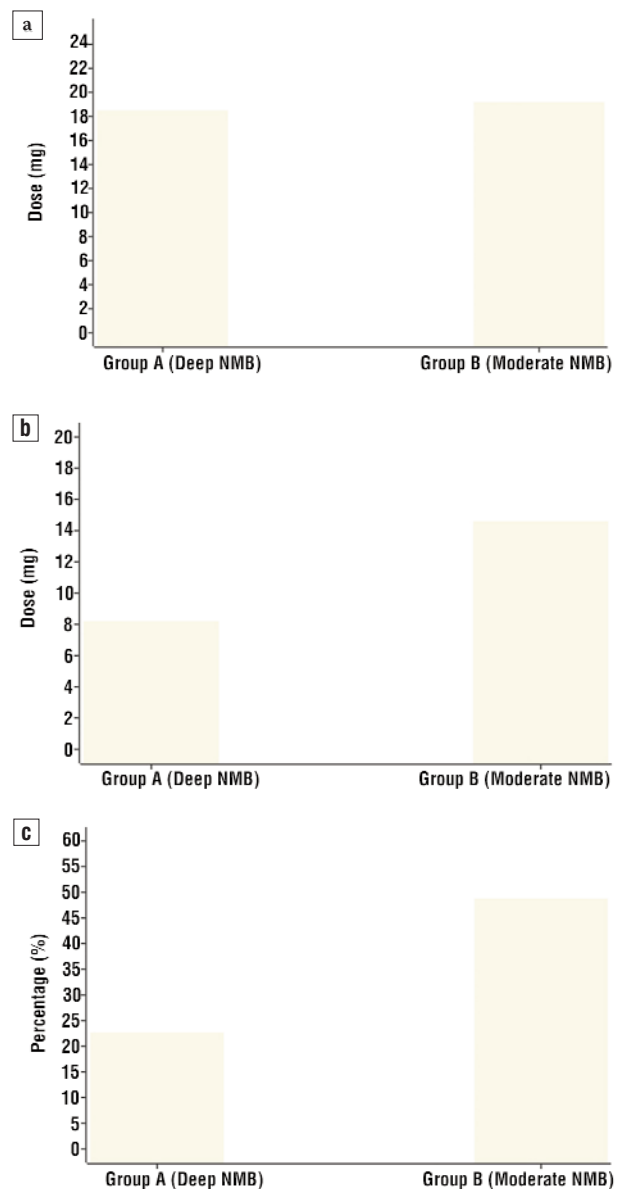


Figure 4 - Perioperative Opioid Consumption and Analgesic Requirements. (a) Intraoperative morphine equivalent dose (mean $\pm$ SD); (b) Postoperative morphine equivalent dose (mean $\pm$ SD); (c) Incidence of postoperative additional analgesic administration (percentage). Blue bars represent Group A (Deep NMB), orange bars represent Group B (Moderate NMB). * denotes $p < 0.05$.

(22.7%) in Group A needing rescue analgesia, whereas Group B had 20 patients (48.8%) ($\chi^2 = 5.54$, $p = 0.019$).

Postoperative Adverse Reactions

The frequency of postoperative adverse responses is summarized in table 3. Adverse event rates were generally modest and similar across groups. Three patients (6.82%) in Group A and four patients (9.76%) in Group B experienced sore throats ($p = 0.663$). Three patients (6.82%) in Group A and three patients (7.32%)

Table 3 - Postoperative Adverse Reactions

Index	Group A (Deep NMB)	Group B (Moderate NMB)	Statistic	p value
Sore throat (n, %)	3 (6.82%)	4 (9.76%)	$\chi^2 = 0.329$	0.663
Nausea and vomiting (n, %)	3 (6.82%)	3 (7.32%)	$\chi^2 = 0.009$	1.000
Dizziness (n, %)	4 (9.09%)	5 (12.20%)	$\chi^2 = 0.281$	0.701
Pruritus (n, %)	0 (0.00%)	0 (0.00%)	NA	NA
Urinary retention (n, %)	4 (9.09%)	2 (4.88%)	$\chi^2 = 0.880$	0.615

*Data are presented as counts (percentages). All adverse events were assessed during the immediate postoperative period (within 24-48 hours). Between-group comparisons were performed using the chi-square test. "NA" denotes "Not Applicable" as no pruritus events occurred in either group. All adverse reactions were mild and self-limiting. No significant differences were observed between groups for any adverse event ($p > 0.05$ for all comparisons), indicating that deep neuromuscular blockade does not increase the risk of postoperative complications. *

in Group B experienced postoperative nausea and vomiting (PONV) ($p = 1.000$). Five patients (12.20%) in Group B and four patients (9.09%) in Group A had dizziness ($p = 0.701$). Two patients (4.88%) in Group B and four patients (9.09%) in Group A had urinary retention ($p = 0.615$). There were no documented instances of pruritus in either group, and statistical analysis was not relevant for this result.

DISCUSSION

The effects of deep versus mild neuromuscular blockade on postoperative pain outcomes in patients following laparoscopic inguinal hernia repair at King Faisal Medical Complex were examined in this multicenter, retrospective, randomized controlled experiment. Our results show that, without increasing adverse events or postponing extubation, deep NMB is linked to notable improvements in early postoperative pain management, decreased opioid doses, and a tendency toward a lower incidence of chronic pain.

Effect on Postoperative Pain

The deep NMB group experienced less immediate postoperative pain, which was the study's most clinically relevant finding. During the first four hours after surgery, patients in Group A reported much lower VAS pain levels; the differences were particularly noticeable at 0.5, 2, and 4 hours. Because it occurs during the time when pain is at its worst after hernia surgery, this early analgesic advantage is very significant (3). Better intraoperative surgical circumstances are probably the cause of the deep NMB group's better pain management. Better muscle relaxation from deep NMB may prevent tissue damage, lessen traction on the ilioinguinal nerves and parietal peritoneum, and eliminate the need for excessive instrument manipulation (5,6). Early postoperative

nociceptive input is known to be influenced by these variables.

The consistent trend toward lower ratings in Group A points to a possible spillover impact of better intraoperative settings, even if the difference in VAS scores at 6 and 24 hours did not achieve statistical significance. This result is consistent with earlier studies by Staehr-Rye et al., which showed that deep NMB enhances the quality of the surgical field and may indirectly alter pain pathways (7).

Chronic Postoperative Pain

With occurrence rates ranging from 10% to 20%, chronic post-surgical pain (CPSP) after inguinal hernia surgery continues to be a major therapeutic problem (4). In our study, Group A had a 2.27% incidence of CPSP at three months, while Group B had a 9.76% incidence. Despite the fact that this difference was not statistically significant—likely because of the limited sample size—the roughly 77% decrease is clinically significant and deserves study. The fact that neither group had CPSP at six months is reassuring and could be a reflection of our institution's generally excellent surgical care and successful multimodal analgesic regimes.

The idea that better intraoperative circumstances may lessen nerve irritation and inflammatory reactions that lead to persistent pain sensitization is supported by the trend toward reduced CPSP in the deep NMB group (10). These results are in line with those of Blichfeldt-Eckhardt et al., who hypothesized that intraoperative variables affecting tissue damage would affect the course of chronic pain (11).

Opioid-Sparing Effect

The substantial opioid-sparing impact seen in the deep NMB group is one of the study's most notable

findings. Patients in Group A needed 43.8% fewer morphine equivalents after surgery and had a 53.5% lower rate of administering rescue analgesia, even though their intraoperative opioid dose was similar. There are several clinical ramifications to this decrease in opioid use.

First, the risk of opioid-related adverse effects, including respiratory depression, nausea, vomiting, constipation, and dizziness, is decreased with fewer opioid exposures (9). Second, given the present opioid epidemic, any approach that reduces postoperative opioid need without compromising pain management is therapeutically beneficial (12). Third, fewer opioids may enable earlier discharge and walking, thereby reducing hospital stays and medical costs (13).

Safety Profile and Feasibility

Deep NMB raises serious concerns about the possibility of longer recovery times and more unfavorable outcomes. In this sense, our results are encouraging. Extubation timings were similar between groups, despite the fact that patients in Group A needed sugammadex reversal more frequently and received noticeably greater doses of rocuronium. This is in line with sugammadex's efficient and reliable reversal, which has been demonstrated to quickly restore even extensive blockage without leaving neuromuscular weakness behind (8).

Additionally, there was a modest and similar rate of postoperative adverse responses in each group. Given the sample size, the marginally higher urine retention rate in Group A (9.09% vs. 4.88%) was not statistically significant and could have been due to chance. Significantly, there were no variations in dizziness, PONV, or sore throat, indicating that deep NMB does not raise postoperative pain or jeopardize patient safety.

Comparison with Previous Studies

Our findings are consistent with other previous investigations. Martini et al. have demonstrated that deep NMB improves laparoscopic surgery operating conditions, which may indirectly affect pain outcomes (5). Bruintjes et al. confirmed that deep NMB enhances the operating environment during laparoscopic procedures in a thorough review and meta-analysis (6). Kim et al. recently reported similar opioid-sparing advantages of deep NMB in laparoscopic colorectal surgery, finding that the technique reduced postoperative pain ratings and the requirement for analgesics (9).

But by focusing on the acute and chronic pain outcomes of inguinal hernia repair—a technique with particular considerations about nerve distribution and chronic pain risk—our study goes beyond these findings. Though pain results were not the main focus, Madsen et al.'s prior study on deep NMB in gynecological laparoscopy indicated better operative circumstances (8).

Limitations of the Study

This study has a number of limitations that should be noted. First, even though the allocation was randomized, the retrospective design raises the possibility of unmeasured confounding and information bias. This worry is somewhat allayed, though comprehensive medical records and its regulated data gathering procedures. Despite being bigger than many prior studies, the sample size ($n = 85$) could have hampered our statistical ability to identify differences in individual adverse events and low-frequency outcomes like CPSP. It's possible that the 3-month CPSP difference's lack of statistical significance reflects a Type II mistake rather than actual equivalency. To conclusively evaluate CPSP differences, a larger multicenter trial with around 150 patients per group would be required, according to a post-hoc power analysis.

Third, although the study is labeled as multicenter with associated facilities, its single-center design may restrict its generalizability to other demographics and healthcare environments. Internal validity is improved, nonetheless, by the standardized surgical methods and anesthetic procedures.

Fourth, we did not use validated measures like the Leiden-Surgical Rating Scale to gather data on surgical field quality, which may have directly demonstrated a connection between deep NMB and better operating circumstances and the resulting pain outcomes (14).

Fifth, the 6-month follow-up period may not capture extremely late-onset pain or long-term functional outcomes like return to work or physical exercise, even if it is sufficient for evaluating chronic pain according to IASP criteria.

Lastly, in order to give a more thorough assessment of the influence of deep NMB on patient-centered outcomes, we did not evaluate quality of life or patient satisfaction metrics.

Future Directions

Future research should focus on:

1. Larger prospective randomized trials adequately

powered to detect differences in chronic pain outcomes.

2. Cost-effectiveness analyses comparing the additional costs of deep NMB and sugammadex against savings from reduced opioid use and shorter recovery.
3. Mechanistic studies investigating the relationship between surgical field quality, tissue trauma, and pain sensitization pathways.
4. Patient-reported outcome measures including quality of life, functional recovery, and return to normal activities.
5. Optimization of NMB monitoring protocols to achieve ideal surgical conditions while minimizing drug administration.

CONCLUSION

This study concludes that, without sacrificing patient safety or delaying recovery, deep neuromuscular blockade during laparoscopic inguinal hernia repair is linked to markedly better early postoperative pain control, fewer opioid needs, and a clinically significant trend toward a lower incidence of chronic pain. For laparoscopic hernia repair, our results lend credence to the inclusion of deep NMB with sugammadex reversal in improved recovery after surgery (ERAS) regimens.

Clinical Significance

Notwithstanding these drawbacks, our results have significant therapeutic ramifications. Deep NMB should be regarded as an important part of multimodal analgesia in laparoscopic inguinal hernia repair because of the enhanced early pain management, decreased opioid needs, and trend toward a lower incidence of chronic pain. Reduced opiate use, fewer rescue analgesia needs, and maybe shorter hospital stays may outweigh the extra expense of larger rocuronium dosages and sugammadex reversal (15). These findings support the regular use of deep NMB with objective monitoring and sugammadex reversal in laparoscopic hernia surgery, especially for individuals who are more likely to experience opioid-related problems or postoperative discomfort.

Conflicts of Interest: none.

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Ethics Approval and Consent to Participate: available.

Availability of data and materials: available.

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