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Original article

Using Intraperitoneal Crystalloid (NS-RL) Solutions for Post-Laparoscopic Surgery Shoulder Pain Reduction Randomized Controlled Trial

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A B S T R A C T

Laparoscopy is the technique of using the "pneumoperitoneum" process to extend and examine the abdominal cavity using CO2. Laparoscopic and other procedures produce pain, which varies in intensity, duration, and type. Crystalloid fluid types, for instance, Normal saline (NS) and Ringer's lactate (RL) solution, aid in reducing laparoscopic pain. Therefore, the research explores intraperitoneal crystalloid solutions in reducing post-laparoscopic surgery shoulder pain. The research adopted a prospective, single-blind study based on a single-center, randomized, and parallel research design. A total of 80 diagnosed patients (40 subjects in each arm) with laparoscopic surgery were randomly recruited at Zintan Medical Center, Alzintan, Libya. Patients were equally divided into Group A (crystalloid solutions) and Group B (routine measures) and were assessed through self-administered pain scores. Through the numeric rating scale (NRS), the research findings revealed significant pain intensity differences between Groups A and B at 6, 12, 24, 48, and 72 hours. In contrast, no significant difference in pain was observed between groups A and B on the fourth and fifth days. Additionally, lower pain intensity was observed in group A than in group B; at 6 hours, the mean pain score for group A and B measured 2.55 and 6.40 at 6 hours, respectively. The intraperitoneal crystalloid solutions infusion aids in reducing pain severity among laparoscopic surgery patients. Future research should address extended follow-up periods to determine the effects of NS and RL interventions. Moreover, stakeholders should implement Ringer's lactate solution (RL) to reduce post-laparoscopic complications

Introduction

Minimally invasive surgeries (MIS) have developed into a widely used medical practice to diagnose the severity of numerous diseases and adverse health conditions. Similarly, laparoscopic surgery (LS) is a minimally invasive surgery (MIS) type, which comprises Laparoscopic Instrumentation (LIs) through trocars via small incisions into the abdominal cavity. This technique has been widely accepted for cholecystectomy, splenectomy, and adrenalectomy [1]. The word laparoscopy originates from the Greek words lapara, meaning "flank or loin," and skopein, meaning "to see, view, or examine," as well as "Keyhole surgery." In addition, the process of "pneumoperitoneum" has been used to extend and examine the abdominal cavity using air [2,3].

Laparoscopy is implemented to identify the site of origin for severe health conditions such as abdominal pain, pelvic pain, abdominal infections, endometriosis, pelvic inflammatory disease, ectopic pregnancy, ovarian cysts, and appendicitis [4,5]. Moreover, numerous studies mention several LS techniques to diagnose adverse diseases, such as abdominal surgery, cancer resection, bariatric surgery for weight loss, and fundoplication for GERD. In addition, urology, obstetrics, pancreatectomy, and hepatectomy employ LS techniques to achieve effective surgical efficacy and lowered post-operative pain, as compared to open surgery. Meanwhile, recent advancements in natural orifice transluminal endoscopic surgery (NOTES), single incision laparoscopic surgery (SILS), and robot-assisted laparoscopic surgery (RALS) reduce the risk of elevated abdominal pressure. However, they require clinical training for implementation [6-8].

Contrarily, fewer risks of LS include experiencing discomfort in the upper abdomen, back, or shoulder, post-laparoscopy. Laparoscopy induces abdominal and shoulder pain due to CO^2 retention between the hepatic dome and right diaphragm [9]. Tas et al. (2013) discussed that diaphragmatic irritation is due to pneumoperitoneum, where the carbon dioxide (CO^2) in the abdominal cavity overstretches muscle fibers in the diaphragm. This stretching leads to the sensory transduction of the phrenic nerve as neuropraxia that enhances abdominal and shoulder pain [10,11]. Likewise, Riedel et al. (1980) demonstrated that most patients experience shoulder rather than subphrenic pain post-laparoscopy. They further elaborated that the peritoneal carbonic anhydrase, formed during surgery, converts CO^2 into carbonic acid inside the

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abdominal cavity [12]. Likewise, the peritoneal hypoxia of CO^2 induces acidosis due to low peritoneal PH, leading to upper abdominal pain [13].
According to Singh et al. (2013), the conversion of CO^2 into carbonic acid on peritoneal surfaces causes shoulder pain, post LS. Another factor of shoulder pain is the long-term Trendelenburg surgical positioning during laparoscopy [14]. However, it is reported that shoulder pain ranges from 35% to 80%, and upper abdominal discomfort affects roughly 90% individuals. The pain lasts for three days or more, the first few hour's post-surgery, or in cases where the pain intensity peaks and subsides into two or three days [15,16]. Likewise, Imbelloni (2014), Kalaivani et al. (2014), and Ko-Iam et al. (2016) highlighted that the frequencies of shoulder pain (SP) ranged from 27 to 80% after laparoscopy, influencing a shoulder discomfort sensation [17-19].
However, numerous anesthetic methods have been used to reduce adverse symptoms of post-laparoscopy, including shoulder pain. Similarly, intrapleural and extradural anesthesia is considered safe for unilateral discomfort, although it is ineffective in relieving pain with phrenic nerve stimulation [11]. The degree of pain alleviation following a laparoscopy has been evaluated using various techniques in several studies [16,20]. Several studies focused on drainage techniques, operation procedures, pneumoperitoneum pressure, temperature, moisture, and different methods to lessen phrenic nerve stimulation [2,21-22]. Meanwhile, numerous drugs have been used to prevent shoulder pain after laparoscopy, such as non-steroidal anti-inflammatory medicines (NSAIDs) [23,24]. The research of Jabbour-Khoury et al. (2005) illustrated that bupivacaine and ketoprofen, as NSAIDs, reduce post-laparoscopic pain across the shoulder and abdomen [25].
Furthermore, opioids such as fentanyl potentially treat acute post-operative pain compared to NSAIDs, but are ineffective for shoulder discomfort [20]. Simultaneously, common analgesics, including paracetamol, opiates, and NSAIDs, have unfavorable side effects and have low efficacy for shoulder pain after laparoscopy [15]. Therefore, potential prophylactic actions are required to avoid post-laparoscopic discomfort and reduce shoulder pain among patients. Intraperitoneal normal saline (IPNS) infusion is a potentially effective method of removing retained CO2 and decreasing post-laparoscopic pain [21,24]. Subsequently, Martini et al. (2013) demonstrated that RL is more adequate than normal saline due to the risk of acidosis and the regulation of acid-base balance [26].
Furthermore, normal saline (NS) and Ringer's lactate (RL) solutions are crystalloid fluids and isotonic solutions that possess balanced electrolytic concentration. Ringer's lactate indicates a 6.5 mean pH and hypo-osmolarity at 272 mOsml/L. It contains electrolytes like plasma, whereas normal saline shows a mean 5.0 pH and 308 mOsml/L hypo-osmolarity. Thus, Ringer's lactate is suitable in comparison to normal saline due to its high pH value [11,27] that potentially neutralizes the acidic peritoneal environment. Furthermore, Suginami et al. (2009) elaborated on the efficient applications of the RL solution to avoid intraperitoneal adhesion with low side effects during surgery. In contrast, Adlan et al. (2022) demonstrated the adverse influence of normal saline on shoulder pain post-operatively [28,29]. Nevertheless, limited research is available regarding the RL method as a better option for removing CO2 retention following laparoscopy. However, this research provided extensive literature to determine the usage of Ringer's lactate (RL) solution for shoulder pain. The study also compared the efficacy of NS and RL for post-laparoscopic treatment, reducing surgical discomfort. This study was conducted to evaluate intraperitoneal crystalloid solutions infusion (normal saline NS or Ringer lactate RL) in reducing shoulder pain after laparoscopic surgery.

Methods

The research adopted a prospective, single-blind study based on a single-center, randomized, and parallel research design. Eighty patients aged 18 years were recruited from hospitals through an accurate sample size calculation. Moreover, the participants were equally divided into Group A and Group B, exposed to crystalloid solutions and routine post-laparoscopic procedures. Both interventions were simultaneously employed to assess crystalloid solutions on post-laparoscopic pain treatment.

Calculation and Selection of Sample Size

The sample size was calculated using PS software (Power and Sample Size Calculations, version 3.1.6) [30]. Based on Cruz et al. (2014), the standard deviation of post-laparoscopic pain was 2.2, and a clinically significant difference of 2 points was assumed [31,32]. With a type I error of 0.05 and a study power of 95%, the required sample size was 40 patients per group (80 patients in total). To account for an anticipated dropout rate of approximately 20%, additional participants were recruited.
Patients scheduled for elective laparoscopic surgery between 1 October 2023 and 30 September 2024 were screened for eligibility according to the predefined inclusion and exclusion criteria one day prior to surgery, as shown in Figure 1, research flow chart. Eligible patients were randomly assigned in a 1:1 ratio to one of two study groups using a computer-generated permuted block randomization method with two blocks, implemented via a web-based system (www.randomization.com). Allocation concealment was ensured using

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sequentially numbered, opaque, sealed envelopes. Each envelope contained a color-coded card indicating Group A (Intervention group) or Group B (Control group).

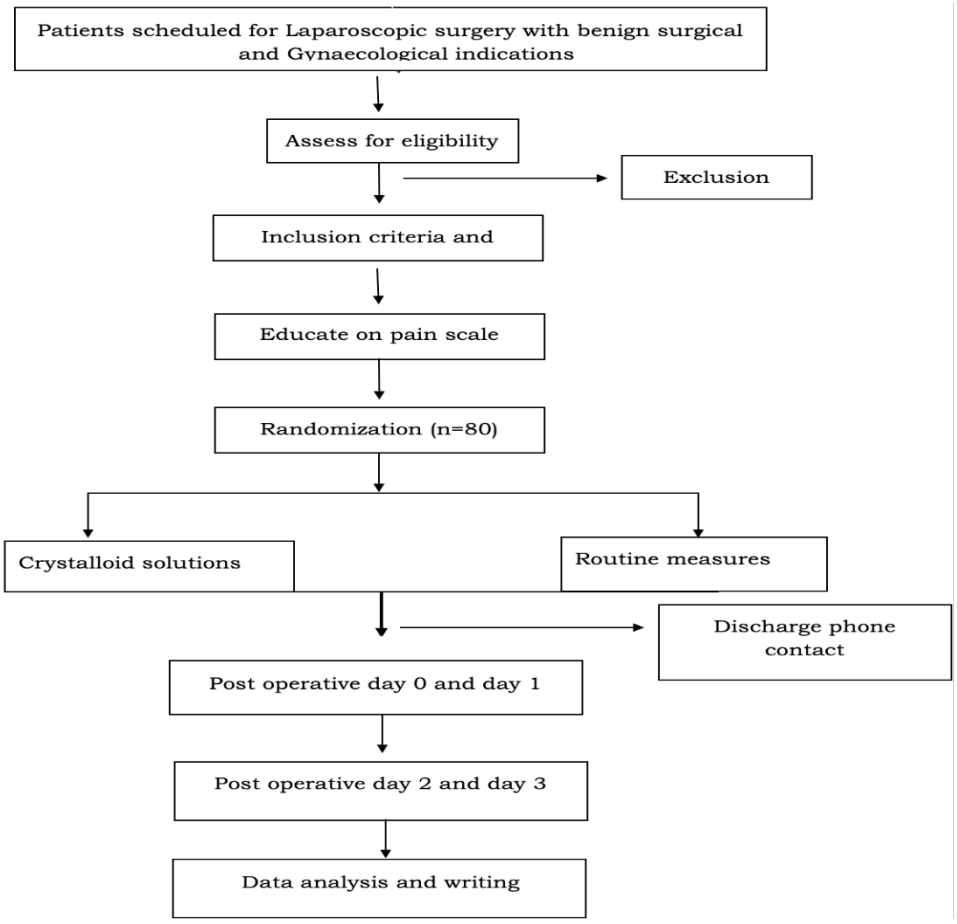

Figure 1. Research Flow Chart

Inclusion Criteria

The research included patients (aged above 18 years old) undergoing laparoscopic surgery with a benign surgical and gynecological indication (laparoscopic cholecystectomy, laparoscopic Appendectomy, and laparoscopic salpingectomy/salpingo-oophorectomy). Moreover, the inclusion criteria were based on the American Society of Anesthesiologists (ASA) classification. The ASA I included normal, healthy, non-smokers, and non-alcoholic individuals. ASA II involved patients with mild systemic disease without substantive functional limitations (BMI <40kg/m^2), well-controlled diabetes mellitus/hypertension, and mild lung disease. and unlimited to current smokers, social alcohol drinkers, pregnancy, and obesity (30<BMI<40, well-controlled diabetes mellitus/hypertension, mild lung disease).

Exclusion Criteria

Patients with prior laparoscopy were excluded. Additionally, patients allergic to non-steroidal anti-inflammatory drugs (NSAIDs), paracetamol, tramadol, and Ringer's lactate solution were excluded. Moreover, pregnant women and intellectually disabled patients were also excluded.

Ethical Consideration

The patients were given informed consent, explaining the research procedure and the pre- and post-intervention risks. Before commencing the intervention procedure, the research sought approval from the ethics committee at Benghazi University. The research procedure was based on the World Medical Association Declaration of Helsinki principles for employing good clinical practice and applicable regulatory requirements. Moreover, the patient's medical records and personal information were kept highly confidential and secured in the institute's system software. Additionally, the participants were assured of complete medical monitoring of adverse post-intervention complications to avoid patient discomfort.

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Operative Technique
All procedures were performed under general anesthesia. Each patient was put in the Trendelenburg position at 20 degrees with both arms tucked in. CO^2 was employed as the distension medium. An intra-abdominal 15mmhg pressure was achieved at a 21/min flow rate, followed by 5mm or 10mm primary trocar insertion at the umbilicus. Additional ports were placed as necessary. Throughout the surgical procedure, the distension pressure was reduced to 12mmhg at a 101/min flow rate at maximum.

Data Collection
Data was collected from patients who underwent laparoscopic operations following the operation technique. Meanwhile, demographics and pre-operative data were collected, and patients were educated regarding pain scores.

Post-Operative Intervention
The post-operative interventions were administered to Group A and Group B patients to assess the pain intensity after laparoscopy. Crystalloids were instilled in Group A with normal saline or Ringer's lactate (15mls/kg) into the upper abdominal cavity. However, trocar sleeve valves were left open during the in-situ solution installation, allowing CO^2 to escape from the abdominal cavity. Further, patients were placed in a neutral position at the end of the intervention. On the contrary, the routine measures given to Group B included regular post-operative analgesia, paracetamol (1g three times per day), ketorolac (30mg twice per day), and opioid drugs. However, regular post-operative analgesia was also given to all patients in Group A. Post-intervention, the instruments and trocars were removed, and the abdominal incisions were closed per the standard procedure. Each patient received standard post-operative care and was discharged per the clinical management team's discretion.

Monitoring and Follow-up
Pain scores were monitored on post-operation days, on day 1 and day 2. In case of early patient discharge on post-operative day 1, the pain scores were collected through subsequent follow-ups.

Measurements
Postoperative pain intensity was assessed using a 10-point Numeric Rating Scale (NRS), where 0 indicated no pain and 10 indicated the worst imaginable pain. Pain scores were summarized as mean ± standard deviation and compared between groups using the independent-samples t-test. In addition, pain severity was categorized into no pain, mild, moderate, and severe grades for categorical analysis.as shown in (Table 1).

Table 1. Pain Levels

Rating	Pain Level
0	No pain
1-3	Mild pain (nagging, annoying, interfering a little with activities of daily living {adls})
4-6	Moderate pain (interferes significantly with ADLs)
7-10	Severe pain (disabling; unable to perform ADLs)

Statistical Analysis
The data was analyzed using SPSS statistical software version 20. The normal distribution, descriptive statistics, and unpaired sample t-test were measured with the Kolmogorov-Smirnov test/Shapiro-Wilk test, chi-square test, Mann-Whitney U test, and Fisher's exact test.

Table 2. Demographic Data of Different Studied Groups

Demographics	Group A (n = 40)		Group B (n = 40)		Test of sig.	P. value
	No.	%	No.	%		
Gender						
Male	9	22.5	11	27.5	X^2 = 0.28	0.60
Female	31	77.5	29	72.5		
Age (Years)						
Min.–Max	19 – 65		20 – 52		t test =1.04	0.29
Mean ± SD.	31.55 ± 12.75		34.18 ± 8.89			
Median	27.5		33.5			

Table 2 tabulates the demographic data of Group A and B patients. Group A included 9 (22.5%) males and 31 (77.5%) females, while Group B included 11 (27.5%) males and 29 (72.5%) females. The gender variation

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showed no significant difference (p-value= 0.60) and (chi-square =0.28). In groups A and B, the average age ranged from (19 to 65) years and (20 to 52) years, respectively. The age difference between both groups showed no significant difference (p-value= 0.29 and t-value =1.04).

Table 3. History of Chronic Diseases and Smoking among Groups

Chronic diseases	Group A (n = 40)		Group B (n = 40)		Test of sig.	P. value
	No.	%	No.	%		
Hypertension	3	7.5	5	12.5	X^2 = 0.55	0.45
Diabetes mellitus	3	7.5	5	12.5	X^2 = 0.55	0.45
Smoking	6	15.0	9	22.5	X^2 = 0.73	0.39

Table 3 demonstrates the history of chronic diseases and smoking among patients from Group A and Group B. The results indicate that 3 (7.5%) patients in group A and 5 (12.5%) in group B were diagnosed with hypertension and diabetes mellitus, respectively. On the contrary, 15% and 22.5% in Groups A and B were active smokers, respectively. These findings revealed no significant differences between both groups regarding hypertension, diabetes mellitus, and smoking (p > 0.05).

Table 4. Duration of Surgery (min) among Studied Groups

Duration of surgery (min)	Group A (n = 40)	Group B (n = 40)	Test of sig.	P. value
Min – Max	35.0 – 180.0	35.0 – 120.0	t= 0.96	0.35
Mean ± SD	65.63 ± 25.37	62.75± 18.52		

Table 4 shows the mean surgery duration for group B at (65.63 ± 25.37) minutes and (62.75 ± 18.52) minutes, respectively, at (p-value =0.35 and t = 0.96).

Table 5. Type of Surgery among Studied Groups

Type of Surgery	Group A (n = 40)		Group B (n = 40)		x^2	P. value
	No.	%	No.	%		
Appendectomy	10	25.0	10	25.0	0.27	0.96
Cholecystectomy	14	35.0	15	37.5		
Ovarian Cystectomy	6	15.0	5	12.5		
Other	10	25.0	10	25.0		

Table 5 shows the distribution of surgical procedures among the two study groups. Cholecystectomy was the most common procedure (35.0% in Group A, 37.5% in Group B), followed by appendectomy (25% in each group). Ovarian cystectomy and other procedures were less frequent. Chi-square analysis indicated no statistically significant difference in the type of surgery between the groups (x^2 = 0.27, p = 0.96). tabulates that Cholecystectomy was highly common among 14 (35.0%) and 15(37.5%) patients in group A and B, respectively, followed by Appendectomy among 10(25.0%) patients in group A and B. Meanwhile, Ovarian Cystectomy was performed in Group A (15%) and Group B (12.5%), whereas other methods showed 10 cases (25%) in each group. No significant difference was found between the two groups (p-value=0.74 and t-value=16.52).

Table 6. Post–Operative Time of Ileus in Hours and Days till Discharge

Post–Operative Time of Ileus		Post–Operative Group B (n = 40)		Test of sig.	P. value
Time of ileus in hours	Min – Max	8.0 – 48.0	8.0 – 24.0	t= 1.12	0.26
	Mean ± SD	16.15 ± 7.21	14.70 ±3.81		
Days till discharge	Min – Max	1.0 – 3.0	1.0 – 3.0	t= 1.27	0.15
	Mean ± SD	1.30 ± 0.56	1.15± 0.42		

Table 6 shows that the duration of postoperative ileus ranged from 8.0 to 48.0 hours in Group A (16.15 ± 7.21 hours) and from 8.0 to 24.0 hours in Group B (14.70 ± 3.81 hours). The length of hospital stay ranged from 1 to 3 days in both groups, with mean values of 1.30 ± 0.56 days in Group A and 1.15 ± 0.42 days in Group B. Independent-samples t-test analysis demonstrated no statistically significant differences between

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the two groups regarding postoperative ileus duration *(t = 1.12, p = 0.26)* or days till discharge *(t = 1.27, p = 0.15)*.

Table 7. Post–Operative Pain Scale among Groups

Post–Operative Pain Scale		Group A (n = 40)	Group B (n = 40)	Test of sig.	P. value
6h	Min – Max	0.0 – 6.0	0.0 – 9.0	t= 8.74	0.001*
	Mean ± SD.	2.55 ± 2.21	6.40 ±1.69		
12h	Min – Max	0.0 – 6.0	0.0 – 9.0	t= 8.55	0.001*
	Mean ± SD.	2.53 ± 2.20	6.28 ±1.76		
24h	Min – Max	0.0 – 6.0	0.0 – 8.0	t= 7.27	0.001*
	Mean ± SD.	1.95 ±2.05	5.18 ± 1.90		
48h	Min – Max	0.0 – 5.0	0.0 – 7.0	t= 5.66	0.001*
	Mean ± SD.	1.23 ±1.74	3.60 ± 2.02		
3rd	Min – Max	0.0 – 4.0	0.0 – 6.0	t= 3.75	0.002*
	Mean ± SD.	0.63 ±1.21	2.0 ± 1.97		
4th	Min – Max	0.0 – 3.0	0.0 – 5.0	t= 1.10	0.35
	Mean ± SD.	0.08 ±0.47	0.28 ±1.03		
5th	Min – Max	0.0 – 0.0	0.0 – 3.0	t= 1.27	0.15
	Mean ± SD.	0.0 ± 0.0	0.10± 0.49		

Table 7 tabulates that the mean pain scale after 6 hours of operation ranges from 2.55 ± 2.21 to 6.40 ± 1.69 in Groups A and B, respectively, with a t-value (8.74). Moreover, after 12 hours, pain was reduced in Group A (2.53 ± 2.20) and Group B (6.28 ± 1.76) with a t-value (8.55). However, 24 and 48 hours highlight mean (1.95 ± 2.05; 5.18 ± 1.90) and (1.23 ± 1.74; 3.60 ± 2.02) in each group, respectively, with 7.27 and 5.66 t-values. Additionally, the third day shows a more reduced pain level with a t-value (3.75) and a low mean in each group. In contrast, the fourth and fifth days indicate t-values of 1.10 and 1.27, respectively, with $p > 0.005$, suggesting a non-significant difference. Meanwhile, the 6, 12, 24, 48 hours, and 3rd day signify the significant differences between groups due to $p < 0.005$.

Table 8. Post–Operative Grading of Pain among Studied Groups

Post–Operative Grading		Group A (n = 40)		Group B (n = 40)		Test of sig.	P. value
		No.	%	No.	%		
6h	No	14	35.0	1	2.5	X^2 =39.25	0.001*
	Mild	10	25.0	2	5.0		
	Moderate	16	40.0	14	35.0		
	Severe	0	0.0	23	57.5		
12h	No	14	35.0	1	2.5	X^2 =38.85	0.001*
	Mild	11	27.5	2	5.0		
	Moderate	15	37.5	16	40.0		
	Sever	0	0.0	21	52.5		
24h	No	18	45.0	1	2.5	X^2 =31.45	0.001*
	Mild	11	27.5	6	15.0		
	Moderate	11	27.5	21	52.5		
	Severe	0	0.0	12	30.0		
48h	No	26	65.0	7	17.5	X^2 =21.06	0.001*
	Mild	7	17.5	7	17.5		
	Moderate	7	17.5	25	62.5		
	Severe	0	0.0	1	2.5		
3rd	No	31	77.5	18	45.0	X^2 =12.25	0.002*
	Mild	8	20.0	11	27.5		
	Moderate	1	2.5	11	27.5		
4th	No	39	97.5	37	92.5	X^2 =2.05	0.35
	Mild	1	2.5	1	2.5		
	Moderate	0	0.0	2	5.0		
5th	No	40	100.0	38	95.0	X^2 =2.05	0.15
	Mild	0	0.0	2	5.0		

Pain scores were assessed using a 0–10 Numeric Rating Scale (NRS).

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Table -8 Numeric pain scores were significantly lower in Group A compared with Group B at 6, 12, 24, and 48 hours postoperatively, as well as on the third postoperative day ($p < 0.05$ for all). By the fourth and fifth postoperative days, pain intensity markedly decreased in both groups, with no statistically significant differences observed ($p > 0.05$). On the fifth postoperative day, all patients in Group A reported no pain.

Table 9. Post-Operative Medications among Different Studied Groups

Post-Operative Medications	Group A (n = 40)		Group B (n = 40)		Test of sig.	P. value
	No.	%	No.	%		
Paracetamol	40	100	40	100	-	-
Ketorolac	40	100	40	100	-	-
Opioids	21	52.5	35	87.5	$X^2 = 11.66$	0.001*

Table 9 shows that all cases received Paracetamol and Ketorolac in groups A and B. In contrast, 87.5% of the studied cases in group B received opioids, contrary to 52.5% in group A, with statistically significant differences ($p < 0.005$). Meanwhile, paracetamol and Ketorolac indicate negligible differences between the two groups. Regarding post-operative complications, wound infection was reported in 5% and 10% among groups A and B, respectively. Vomiting was reported in 25% and 37.5% of group A and group B, respectively. Moreover, lung atelectasis was reported in 10% and 17.5% among groups A and B, respectively. Fever was reported in only 2.5% and 7.5% among groups A and B, respectively, as shown in Table 10. The findings show a non-significant difference between groups with $p > 0.005$.

Discussion

The current research determines the influence of intraperitoneal crystalloid solutions infusion (normal saline NS or Ringer lactate RL) after laparoscopic surgery. The findings revealed a significant difference between the two groups on the first and second days that were given NS and RL. However, the study demonstrated more health complications after surgery among NS patients than RL. In this study, infused intraperitoneal normal saline or Ringer's lactate (15mls/kg) was used to reduce the remaining amount of CO2 between the diaphragm and liver. Patients were placed in a 30-degree Trendelenburg position, which allowed them to infuse a minimal amount of saline. This eliminates the potential gas space between the liver and diaphragm, enabling shoulder pain. The total amount of dissimilar saline was infused in each patient due to variances in liver size.

However, the rapid distension of the peritoneum may be associated with overstretching of the diaphragmatic muscle fibers, tearing of blood vessels, traumatic traction of nerves, and release of inflammatory mediators. The prolonged presence of shoulder-tip pain suggests excitation of the phrenic nerve. Therefore, there was a statistically significant correlation between the width of the gas bubble and the pain score. Likewise, the study's results were similar to the research of Davari-Tanha et al. (2019) on low pain levels on the first day of post-surgery [33]. In addition, this study revealed significant differences in pain outcomes between patients who received intraperitoneal crystalloid solutions infusion (group A) compared to those who underwent routine measures (group B) following laparoscopic procedures. Throughout the immediate post-operative period (6, 12, 24, 48, and 72 hours), group A consistently reported lower pain scores on the Numeric Rating Scale (NRS) compared to group B, with these differences being statistically significant ($p < 0.001$).

Specifically, at 6 hours post-surgery, the mean NRS score was 2.55 in group A, significantly lower than the score of 6.40 observed in group B. Both groups showed decreased NRS scores over time, indicating improved pain levels as patients recovered. By the fifth day post-surgery, group A reported minimal pain with a mean NRS score approaching 0, whereas group B still experienced varying degrees of pain with a mean score of around 0.10. However, the differences in pain scores between the two groups were not statistically significant on the fourth and fifth days. Moreover, the consistently lower scores in group A during the critical early post-operative period suggest a potential benefit of intraperitoneal crystalloid solutions infusion in managing immediate post-laparoscopic pain.

Similarly, the decrease in pain scores aligned with previous studies demonstrating the analgesic benefits of intraperitoneal fluid instillation [33]. This may be the longer drug efficacy in the peritoneal cavity, as mentioned in Muzii et al. (2005), which elaborated that Ringer's lactate solution absorbed approximately 30-60ml per hour than traditional solutions [34]. On the contrary, the research of Tsai et al. highlighted NS as being more effective than local anesthetic ropivacaine-morphine in alleviating pain, contrary to the current study's results [35]. These findings provided compelling evidence for the effectiveness of intraperitoneal crystalloid solutions infusion in immediate post-operative pain management. Moreover, the study provided

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deeper insights into refining perioperative care protocols, directing future studies to assess long-term outcomes of RL intervention.

Limitations

The study is limited to short-term follow-ups, so the effects of nerve stimulation (NS) and relaxation (RL) are only assessed in the immediate postoperative period. It also focuses solely on comparing their efficacy in reducing shoulder pain after laparoscopy, without exploring long-term outcomes or broader applications.

Conclusion

Laparoscopic surgery (LS) is a type of minimally invasive surgery (MIS) that induces abdominal and shoulder pain due to CO2 gas retention. However, the study assessed the efficacy of intraperitoneal crystalloid (NS-RL) solutions among patients and divided them into two groups concerning interventions. The findings support the adoption of intraperitoneal crystalloid solutions infusion as a beneficial adjunctive therapy to reduce early post-laparoscopic pain effectively. Incorporating this approach into routine clinical practice could enhance patient comfort and satisfaction during the critical initial stages of recovery following laparoscopic procedures.

Recommendations

Future research should incorporate extended follow-up periods to better evaluate the sustained effects of nerve stimulation (NS) and relaxation (RL) interventions. In addition, future studies should emphasize comparing RL with other postoperative management strategies to establish its efficacy with greater validity. Finally, stakeholders are encouraged to adopt RL practices as part of routine care to help reduce post-laparoscopic complications.

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