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The influence of the pulmonary recruitment maneuver on post-laparoscopic shoulder pain in patients having a laparoscopic cholecystectomy: a randomized controlled trial

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Abstract

Background Post-laparoscopic shoulder pain is very common after laparoscopy. One method to reduce postoperative shoulder pain is the pulmonary recruitment maneuver. It is used to reduce post-laparoscopic shoulder pain. This study utilizes a truly experimental, double-blinded, prospective randomized design to assess the effect of pulmonary recruitment maneuvers on post-laparoscopic shoulder pain after laparoscopic cholecystectomy.

Methods Sixty patients were allocated randomly into two groups. The intervention group received five manual pulmonary inflations for 5 s at a maximum pressure of 25 cm H_2O. The control group included patients whose residual CO_2 gas was evacuated from the abdominal cavity using passive exsufflation as the routine method at the end of surgery by abdominal massage. Gentle abdominal pressure was applied to facilitate CO_2 gas removal.

Results When Ramsay's Sedation Score's results were compared between the two groups after the operation, there was no statistically significant difference between the two groups during the first and (p value = 0.20) second (p value = 0.61) hours. A repeated measures ANOVA revealed that the pulmonary recruitment maneuver is significant (p-value 0.001) and had a high effect size (0.527) in reducing shoulder pain among laparoscopic cholecystectomy patients after controlling the effect of other covariate patient characteristics.

Conclusion Utilizing a pulmonary recruitment maneuver at the end of laparoscopic surgery reduces shoulder pain.

Keywords Shoulder pain · Laparoscopy · Maneuvers · Cholecystectomy

Laparoscopy is one of the procedures used to diagnose and manage different types of medical problems. Laparoscopy involves the insufflation of gas in the abdomen by an endoscope [1], which is a minimally invasive operation. To reduce postoperative pain in the small surgical site, reduced the length of stay in the hospital, and the absence of large surgical scars compared with conventional laparotomy [2].

Despite that, more than 80% of patients complain of severe pain after laparoscopic surgery and need pain relief [3], post laparoscopic shoulder pain is very common after laparoscopy. About 35% to 80% of patients complain of Post Laparoscopic shoulder pain (PLSP) which is ranged from mild to severe levels [1, 3, 4]. Post-operative shoulder pain is associated with increased morbidity related to the severity of pain, which sometimes stays for more than 3 days and is described as worse than the pain from the actual procedure [5]. Post-operative shoulder pain may cause a length of stay, delay discharge from the hospital, and sometimes readmission to the hospital [1].

However, it appears that carbon dioxide gas plays a significant role in its mechanism by causing peritoneal stretching and diaphragmatic irritation [6–8], additionally, leftover carbon dioxide trapped between the liver and the diaphragm after laparoscopic surgery caused phrenic nerve irritation which results in post-laparoscopy shoulder pain [6, 9, 10].

There are several methods to reduce postoperative shoulder pain, such as the use of CO_2 alternative gases for insufflating [11], the use of low-pressure in place of standard -pressure for pneumoperitoneum [12], actively expelling out

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of gas [13], the use of local anesthesia to the peritoneal cavity [14], pulmonary recruitment maneuver [15], or combination between these methods [2, 16, 17].

The pulmonary recruitment maneuver (PLM) is an effective and simple method to reduce PLSP. This procedure involves increasing the positive airway pressure by exerting manual lung inflation, which increases the pressure inside the chest, so it is easy to remove carbon dioxide from the peritoneal cavity. PRM is simple to perform, does not require any additional equipment or medication, and appears to be the most promising technique for reducing PLSP [18–20]. Hence, this study aims to assess the effect of pulmonary recruitment maneuvers (PRM) on post-laparoscopic shoulder pain after laparoscopic cholecystectomy.

Materials and methods

A true experimental, double-blind, prospective randomized study, was conducted between November 1st, 2020, and May 1st, 2021, in the post-operative surgical ward, at Rafida Hospital. The estimated sample size was based on $\alpha = 0.05$ and power 0.80 and assuming a mean 55% incidence reported in the literature (35 to 80%) is 60 patients in both groups [21]. We recruited patients between the ages of 18 and 60 years, ASA physical status I or II, who were scheduled for an elective laparoscopic cholecystectomy. Patients with ASA grades 3 and above, as well as those with preoperative symptoms of severe acute cholecystitis, choledocholithiasis, pancreatitis, and multiple adhesions, were excluded from this study. In addition, patients who have a history of lung diseases such as chronic obstructive pulmonary disease, restrictive lung disease, or pneumothorax, or had a history of thoracic or shoulder surgery. In addition, patients who complain of septic contamination of the peritoneal cavity after surgery, and patients' conversion to a laparotomy, and if the operation time is more than 3 h, were excluded from the study. Besides, patients complained of chronic shoulder pain or epigastric pain or serious adverse effects, which make it difficult to assess pain, and pregnant women were excluded.

Patients who met the inclusion criteria were randomly allocated to either the PRM or the control group; randomization (1:1) was based on a computer-generated random number table. The patient was secured with one 18G cannula and monitored by standard monitoring (heart rate, SPO_2, NIBP, RR, and 12-lead ECG). After that, induction was done by intravenous propofol 2–4 mg/kg, fentanyl 1–2 mg/kg, and atracurium 0.5–0.6 mg/kg with endotracheal intubation and was further maintained with sevoflurane 2–3 vol%.

Ventilation was done in a volume-controlled mode with a tidal volume of 7–9 ml/kg. Ventilation frequency was regulated to maintain an ET CO_2 partial pressure between 35 and 40 mm Hg. No patient received positive end-expiratory pressure (PEEP). The level of neuromuscular block was measured by acceleromyography (Fisher and Paykel, healthcare, innervation 272). Train-of-four (TOF) was monitored during the operation and an additional atracurium bolus of 0.15 mg/kg will be administered when the TOF value is at 25%.

An experienced laparoscopic surgery team performed all laparoscopic procedures. Laparoscopy was done by the use of CO_2 gas as the distension medium. The intra-abdominal gas pressure and the total volume of gas delivered during laparoscopy were monitored. The flow of insufflation gas did not exceed 2 l/min when creating the pneumoperitoneum. The CO_2 gas pressure was set at 14 mm Hg during laparoscopy. A 4-trocar technique was used (10 mm umbilical port; 10 mm epigastric and 2 lateral ports, each of them 5 mm). Strict attention was paid to maintaining the intra-abdominal pressure of about 12 mm Hg during the procedure. All patients were placed in the 15°–20° Trendelenburg position. Following the surgery, the lateral ports were removed and the intra-abdominal gas was removed via the main umbilical port. The time spent from the operation between the two groups was about 1 h to1:15 h, it was almost between both control and intervention group, all patients have the same type of surgery and the same method to apply by the surgeon. They have some difficulty for patients who have previous abdominal surgery related to adhesion. They take more time and if blood loss occurred they requested for blood transfusion. There are some technical challenges such as change of patient position in intervention group to trendelenburg position to eliminate potential CO_2 before closure of surgical wound.

The intervention group included patients who received the PRM which consisted of five manual pulmonary inflations, where each positive pressure inflation was done for 5 s at a maximum pressure of 25 cm H_2O, manually by using the APL valve in the anesthesia machine. The patient was in a Trendelenburg position (30°). The fifth positive pressure inflation lasted for approximately 5 s. During that time, the patient was monitored, while the anesthesiologist performed PRM. The surgeon was instructed to open the trocar valve fully to remove intraperitoneal CO_2 gas [16].

A control group included patients whose residual CO_2 gas was evacuated from the abdominal cavity using passive insufflation by abdominal massage as the routine method at the end of surgery [11]. In the intervention group, patients were in a Trendelenburg position before the PRM, and the patients' positions were maintained until the PRM was completed. Patients received the PRM at a pressure of 25 cm H_2O. During this procedure, the port (or trocar) was fully open to allow the CO_2 gas to escape from the peritoneal cavity, and then the main port was removed. Participants and the research staff assessing the outcomes were blinded to patient data [22]. Extubation for all patients is done in

the same way by the use of a reversal agent (neostigmine 2.5 mg + atropine 1 mg). Then the patient was moved to a horizontal position, the laparoscopic tools were removed, and the surgical wounds were closed.

On a VAS, postoperative analgesia was provided with paracetamol 1000 mg IV when a patient complained of postoperative pain greater than 4 on a VAS. Questionnaires were asking about shoulder pain given to patients after surgery. Patients answered the questionnaires by describing the incidence and severity of pain during the first 2, 6, 12, and 24 h after the surgery by using a visual analog scale (VAS). The patients by themselves put a mark along the visual analog scale from 0 (no pain) to 10 (extreme pain). Before that, all patients were assessed for sedation level by the use of the Ramsay Sedation Scale, exactly before beginning the pain assessment, after 2 h of finishing surgery. In addition, we as investigators recorded some parameters on the case report forms: operation time, vital signs, duration of surgery, use of analgesics, length of stay, and demographical data [16].

Statistical analysis

The data were analyzed using the SPSS software statistical package version 21. Means, standard deviations, and percentages were used to describe the data for each group; the *t*-test was used to assess the anthropometrics and age of participants, as well as hemodynamic parameters and shoulder pain level statistical test was used to examine the effect of PRM, and repeated measures ANOVA with a Greenhouse–Geisser correction and post hoc tests were used to assess the VAS of shoulder pain.

Results

Medical history and gender of participants

When the two groups (control & intervention) were compared in terms of gender, the results showed that the two groups have roughly the same proportions and there is no statistically significant difference ($X^2 = 0.067$ & p-value = 0.795) due to gender or disease history (Table 1).

Although there was no statistically significant difference, the percentage of females and ASA1 in the intervention group were slightly higher in comparison with the control group (56.7% (gender in the intervention group) and 86.7% (ASA physical status in the intervention group) vs. 53.3% (gender in the control group) and 76.7% (ASA physical status in the control group). On the contrary, the proportion of patients with hypertension and diabetes was slightly lower among the intervention group when compared with the control group (10% vs. 6.7%, respectively).

Table 1 Anthropometrics parameters of participants ($N = 30$)

Group	N (%)	Mean (SD)	t (p-value)	X^2 (p-value)
Age				
Control	30 (100)	43.3 (9.9)	−0.678	
Intervention	30 (100)	44.9 (8.6)	(0.501)	
ASA physical status				
Control	30 (100)			1.002
Intervention	30 (100)			(0.317)
Co-morbidity				
Control	30 (100)			0.617
Intervention	30 (100)			(0.893)
Gender				
Control	30 (100)			0.067
Intervention	30 (100)			(0.795)
Height				
Control	30 (100)	172.6 (6.7)	−0.477 (0.635)	
Intervention	30 (100)	173.5 (7.7)		
Weight				
Control	30 (100)	80.7 (13.7)	−0.891 (0.376)	
Intervention	30 (100)	83.4 (8.9)		
BMI				
Control	30 (100)	27.1 (4.5)	−0.663 (0.510)	
Intervention	30 (100)	27.7 (2.69)		

SD std. deviation, *BMI* body mass index, % frequency, *N* number

The *t*-test showed that the two groups had approximately the same anthropometric characteristics as well as the ages of the participants. The average age of the participants of laparoscopic cholecystectomy patients in the control group was 43.3 years, which is slightly higher than the average age of the intervention group (44.9 years). While the anthropometric parameters of patients in the interventional group were slightly higher than those of the control group (height = 173.5 vs. 172.6, weight = 83.4 vs. 80.7, and BMI 27.7 vs. 27.1, respectively) (Table 1).

As for the averages of hemodynamics parameters among the participants of the two groups before the pulmonary recruitment maneuver, the *t*-test revealed that the two groups had very close readings and were within the normal range for an adult patient (normal range for vital signs). Although the heart rate of intervention group participants was slightly higher (79.0/m vs. 76.1/m), the diastolic and systolic blood pressure and blood O_2 saturation rates were slightly lower among the intervention participants group, compared with the control participants group (14.4 vs. 14.7, 132.2 vs. 134.4, 77.9 vs. 80.9, & 98.63 vs. 98.40, respectively).

When comparing the heart rate readings between the two groups (control and intervention) during the study

observation period before the pulmonary recruitment maneuver and up to 24 h after the pulmonary recruitment maneuver of the patients who underwent a laparoscopic cholecystectomy, it was revealed through the use of the statistical *t*-test that there was no statistical significance (*p* values > 0.05) difference between the two groups as the meetings were close and within normal limits during the whole study observation period.

Although there was no statistically significant (*p* values > 0.05) difference and the readings were within the normal range, the interventional participants' heart rate was slightly higher throughout the observational study period.

When comparing the respiratory rate readings between the two groups (control & intervention) during the study observation period, before the pulmonary recruitment maneuver and up to 24 h after the pulmonary recruitment maneuver of the patients who underwent a gallbladder excision, it was revealed through the use of the statistical *t* test that there was no any statistical significance (*p*-values > 0.05) difference between the two groups as the RR readings were close and within normal limits during the whole study observation period except at 2nd and 24th h post-operative (*p* values = 0.008 & 0.02 respectively). The respiratory rate of the interventional participant's group; which underwent pulmonary recruitment maneuver, was slightly higher throughout the observational study period.

Although there was a statistical significance (*p* values < 0.05) difference at two-time points (2nd and 24th h post-operative), the readings of RR at all-time intervals were within the normal limit (13.3–14.9/m).

When comparing the systolic blood pressure readings between the two groups (control and intervention) during the study observation period before the pulmonary recruitment maneuver and up to 24 h after the pulmonary recruitment maneuver of the patients who were undergoing laparoscopic cholecystectomy, it was revealed through the use of the statistical *t* test that there was no statistical significance (*p* values > 0.05) difference between the two groups as the meetings were close and within normal limits during the whole study observation period.

Although there was no statistically significant difference (*p*-values > 0.05) and the readings were within the normal range, the heart rate of the control participants group, who underwent the pulmonary recruitment maneuver, was slightly higher throughout the observational study period.

When comparing the diastolic blood pressure readings between the two groups (control and intervention) during the study observation period before the pulmonary recruitment maneuver and up to 24 h after the pulmonary recruitment maneuver of the patients undergoing laparoscopic cholecystectomy, it was revealed through the use of the statistical *t*-test that there was no statistical significance (*p* values > 0.05) difference between the two groups as the meetings were close and within normal limits during the whole study observation period.

Although there was no statistically significant (*p* values > 0.05) difference and the readings were within the normal range, the diastolic blood pressure of the control participants was slightly higher throughout the observational study period.

When comparing the O_2 sat. readings between the two groups (control and intervention) during the study observation period before the pulmonary recruitment maneuver and up to 24 h after the pulmonary recruitment maneuver of the patients who underwent laparoscopic cholecystectomy, it was revealed through the use of the statistical *t* test that there was no statistical significance (*p* values > 0.05) difference between the two groups as the meetings were close and within normal limits during the whole study observation period (Table 2).

Although there was no statistically significant difference (*p* values > 0.05) and the readings were within the normal range, the O_2 saturation of the control participants group, who underwent pulmonary recruitment maneuver, was slightly lower throughout the observational study period.

When Ramsay's Sedation Score's results were compared between the two groups after the operation, there was no statistically significant difference between the two groups during the first and (*p* value = 0.20) second (*p* value = 0.61) hours. In both groups, all patients of laparoscopic cholecystectomy patients switched from a brisk response or response to a verbal stimulus during the first hour after the operation to agitated and anxious during the second post-operative hour (Table 3).

It is clear and unequivocal that in the laparoscopic cholecystectomy participants in the intervention group who had the pulmonary recruitment maneuver applied, their level of shoulder pain was lower than those in the control group to whom the pulmonary recruitment maneuver was not applied, and this difference was statistically significant during the entire (2nd [*p* value = 0.001], 6th [*p* value 0.001], 12th [*p* value 0.001], and 24th [*p* value 0.001]) period of observation of the study (Table 4).

The use of the pulmonary recruitment maneuver on the participants of cholecystectomy patients in the interventional group led to a statistically significant reduction in the amount of total analgesia (*p* value < 0.001) used after the operation, as well as the length of time to ask for the first rescue analgesia dose of analgesia (*p* value < 0.001). Duration of the surgery was the same in both groups (Table 5).

A repeated measures ANOVA revealed that the pulmonary recruitment maneuver is significant (*p*-value 0.001) and had a high effect size (0.527) in reducing shoulder pain among laparoscopic cholecystectomy patients after controlling the effect of other covariate patient characteristics (Table 6).

Table 2 Hemodynamic parameters readings intervals comparison between intervention vs. control group

Hemodynamic parameters	Group	Mean (SD)	*t*	*p*-value
HR before PRM	Control	76.1 (9.3)	− 1.276	0.207
	Intervention	79.0 (8.2)		
HR immediately after PRM	Control	77.4 (8.7)	− 0.96	0.337
	Intervention	79.6 (8.5)		
HR after 2 h	Control	74.9 (7.4)	− 1.30	0.197
	Intervention	77.6 (8.1)		
HR after 6 h	Control	75.4 (7.4)	− 1.02	0.310
	Intervention	77.4 (7.7)		
HR after 12 h	Control	75.2 (7.1)	− 0.96	0.337
	Intervention	77.1 (8.0)		
HR after 24 h	Control	74.4 (6.5)	− 1.74	0.086
	Intervention	77.5 (7.5)		
RR before PRM	Control	14.7 (1.0)	1.183	0.242
	Intervention	14.4 (1.1)		
RR immediately after PRM	Control	14.7 (1.0)	1.183	0.242
	Intervention	14.4 (1.1)		
RR after 2 h	Control	14.9 (1.3)	2.741	0.008
	Intervention	14.1 (1.0)		
RR after 6 h	Control	14.2 (1.3)	1.842	0.071
	Intervention	13.6 (1.2)		
RR after 12 h	Control	13.8 (1.2)	1.709	0.093
	Intervention	13.3 (1.0)		
RR after 24 h	Control	14.1 (1.1)	2.394	0.020
	Intervention	13.3 (1.2)		
SBP before PRM	Control	134.4 (10.5)	0.929	0.357
	Intervention	132.2 (7.3)		
SBP immediately after PRM	Control	135.7 (10.6)	1.356	0.180
	Intervention	132.6 (6.6)		
SBP after 2 h	Control	133.0 (10.2)	0.951	0.346
	Intervention	130.9 (6.4)		
SBP after 6 h	Control	130.8 (8.7)	0.562	0.577
	Intervention	129.7 (5.7)		
SBP after 12 h	Control	131.5 (9.4)	1.069	0.289
	Intervention	129.3 (5.9)		
SBP after 24 h	Control	131.4 (8.8)	1.322	0.191
	Intervention	128.9 (4.8)		
DBP before PRM	Control	80.9 (10.6)	1.270	0.209
	Intervention	77.9 (7.7)		
DBP immediately after PRM	Control	81.0 (9.9)	1.531	0.131
	Intervention	77.5 (7.3)		
DBP after 2 h	Control	79.0 (9.6)	1.252	0.216
	Intervention	76.3 (7.2)		
DBP after 6 h	Control	77.5 (7.7)	1.085	0.282
	Intervention	75.6 (5.7)		
DBP after 12 h	Control	77.2 (7.8)	1.076	0.286
	Intervention	75.3 (5.8)		
DBP after 24 h	Control	77.7 (7.1)	1.465	0.148
	Intervention	75.4 (4.9)		
O_2 sat before PRM	Control	98.40 (1.8)	− 0.551	0.584
	Intervention	98.63 (1.5)		

Table 2 (continued)

Hemodynamic parameters	Group	Mean (SD)	*t*	*p*-value
O_2 sat immediately after PRM	Control	98.5 (1.3)	0.107	0.915
	Intervention	98.5 (1.1)		
O_2 sat after 2 h	Control	98.4 (0.9)	0.000	1.00
	Intervention	98.4 (0.7)		
O_2 sat after 6 h	Control	98.3 (1.4)	− 0.636	0.528
	Intervention	98.5 (1.0)		
O_2 sat after 12 h	Control	98.7 (1.0)	− 0.935	0.354
	Intervention	98.9 (0.9)		
O_2 sat after 24 h	Control	98.8 (1.0)	0.137	0.891
	Intervention	98.7 (0.8)		

PRM pulmonary recruitment maneuver, *HR* harte rate, *RR* respiratory rate, *SBP* systole blood pressure, *DBP* diastolic blood pressure, *O_2 sat* oxygen saturation

Table 3 Comparison of post-operative Ramsay Sedation Score in both (control vs. intervention) groups at 1st & 2nd h ($N=30$)

Group	Mean (SD)	*t*	*p*-value
Post-operative Ramsay Sedation Score			
After 1 h			
Control	3.37 (0.490)	− 1.29	0.201
Intervention	3.53 (0.507)		
After 2 h			
Control	1.40 (0.498)	− 0.513	0.610
Intervention	1.47 (0.507)		

SD standard deviation

Table 4 Comparison of post-operative shoulder pain level among the two (control vs. intervention) groups

Group	Mean (SD)	*t*	*p*-value
Shoulder pain level			
After 2 h			
Control	9.03 (0.92)	3.59	0.001*
Intervention	8.13 (1.00)		
After 6 h			
Control	7.40 (1.30)	8.25	< 0.001*
Intervention	4.77 (1.16)		
After 12 h			
Control	4.67 (1.74)	7.93	< 0.001*
Intervention	1.83 (0.87)		
After 24 h			
Control	2.07 (1.31)	5.30	< 0.001*
Intervention	0.67 (0.606)		

SD standard deviation

*$p<0.001$ = Significance level (two-tailed)

Table 5 Comparison of post-operative time for first rescue analgesia, total amount of rescue analgesia, & duration of surgery among the two (control vs. intervention) groups

Group	*N*	Mean	SD	*t*	*p*-value
Time for first rescue analgesia in min					
Control	30	118.17	9.42	− 4.35	< 0.001
Intervention	30	130.00	11.52		
Total amount of rescue analgesia in first 24 h op					
Control	30	3.13	0.681	3.84	< 0.001
Intervention	30	2.43	0.728		
Duration of surgery in min					
Control	30	56.97	8.48	0.58	0.560
Intervention	30	55.67	8.68		

SD stander deviation

Table 6 Repeated measures test for post-operative shoulder between groups and controlling effect of participants' characteristics

Source	df	Post-operative shoulder pain			
		MS	*F*	*p*-value	ηp^2
Intercept	1	38.907	10.375	0.002*	0.164
Gender	1	2.519	0.672	0.416	0.013
Age	1	4.140	1.104	0.298	0.020
BMI	1	0.273	0.073	0.788	0.001
ASA physical status	1	0.213	0.057	0.813	0.001
Comorbidity	1	0.096	0.026	0.873	0.000
Group	1	221.106	58.960	0.000*	0.527
Error	53	3.750			

MS mean square, ηp^2 partial eta squared, *BMI* body mass index

*$p<0.001$ = Significance level (two-tailed)

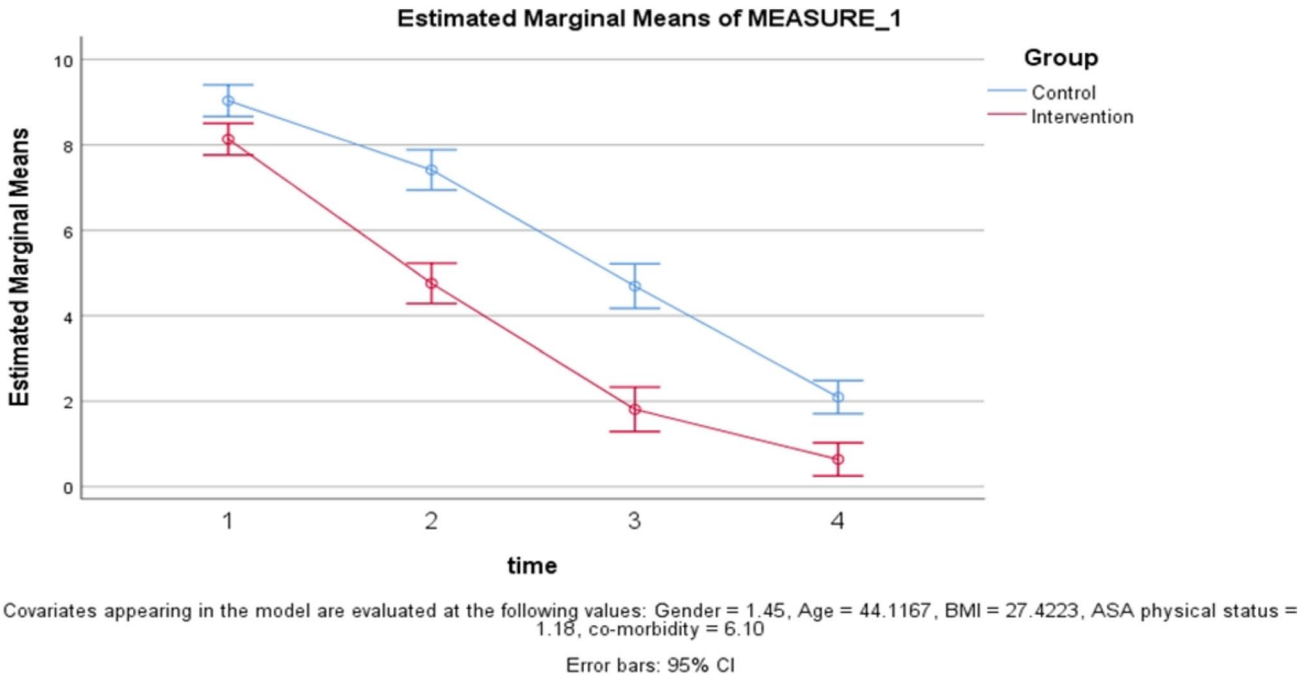

Fig. 1 Shoulder pain level readings (control vs. intervention) Comparison during the study observation period. Post hoc tests using the Bonferroni correction revealed that there was a statistically significant ($p < 0.001$) reduction in shoulder pain level through all points time (2 h, 6 h, 12 h, & 24 h)

A repeated measures ANOVA with a Greenhouse–Geisser correction determined that the mean VAS of shoulder pain differed statistically significantly between time points [F (2.43, 128.8) = 8.17, $p < 0.001$] (Fig. 1).

Discussion

In this randomized prospective double-blind study, we assess the effect of the pulmonary recruitment maneuver on post-laparoscopic shoulder pain for patients undergoing laparoscopic cholecystectomy. Moreover, it assesses if the pulmonary recruitment maneuver can maintain hemodynamic stability among patients who have undergone laparoscopic cholecystectomy.

In our study, there are no statistical differences between the control group and intervention group when compared in gender, age, disease history, ASA physical status, baseline hemodynamic parameters, and Duration of surgery which are similar to a lot of studies conducted to same purpose [11, 16, 23, 24].

Similar to Lee, Park [24], the present study showed that PRM does not affect the stability of hemodynamic parameters as there were no significant differences in hemodynamic parameters between both groups in this study, except in respiratory rate at 2 h and 24 h. And these differences in RR had very little clinical impact, as its values are still within the normal range and they are stable. On the other hand, a recent one, conducted in Egypt by Refaat et al. [25], found that HR marginally significant decrease among the PRM group during 1st h and 3rd h.

Similar to our study, there were no statistical differences in the Harte rate, but they discovered that the pulmonary recruitment maneuver improved arterial oxygenation in healthy patients undergoing intraoperative laparoscopic cholecystectomy [26]. Furthermore, there were few studies in the literature reporting the effect of pulmonary recruitment maneuvers on hemodynamic stability [25]. In a study Güngördük, Aşıcıoğlu [26] that was conducted in 2008, hemodynamic stability was not reported, but they found that there were no pulmonary or cardiovascular complications related to PRM.

Our findings show that the pulmonary recruitment maneuver significantly reduces post-laparoscopic shoulder pain in a 4-time point of observation between the control and intervention groups, which is consistent with a meta-analysis of randomized controlled trials [18] and another randomized, controlled, triple-blind study by [27]. In contrast

with a study Davari-Tanha, Samimi [27], which was applied to gynecologic laparoscopic procedures, follow-up was like our study at different points of time (after 2, 6, 12, and 24 h) in different sites (shoulder pain, upper abdominal pain, incision site pain), it showed that PRM was better in decreasing shoulder and upper abdominal pain after laparoscopic surgery.

In a study conducted by Liu, Ma [28], he stated that PRM is effective in decreasing the incidence and intensity of shoulder pain with intraperitoneal ropivacaine in patients undergoing conventional laparoscopic procedures. And PRM is more effective than an intraperitoneal infusion of NS [27], which is consistent with our study that PRM reduces PLSP even when compared with other interventions or when PRM is combined with other interventions such as intraperitoneal bupivacaine [16], or intraperitoneal saline (IPS) [20, 29].

In addition to the benefits of the use of PRM, as it doesn't need additional devices and saves time [11, 19], a network meta-analysis of randomized controlled trials Kietpeerakool, Rattanakanokchai [20] found that PRM with 40 cm H_2O is a promising intervention to reduce shoulder pain and that PRM is the first choice to diminish postoperative shoulder pain even with other interventions or alone, but they're follow up was for 48 h, which is more than our study, which was for 24 h and on the patient under gynecologic laparoscopy, which is consistent with our result.

After the laparoscopy procedure, pain arises from the procedure site, wound site, and pneumoperitoneum. Pneumoperitoneum causes referred shoulder pain, which may stay for 24 h to 72 h [26, 30]. Although there is no clear hypothesis to understand the mechanisms of post-laparoscopic shoulder pain, it could be explained by the CO_2 remaining in the peritoneal cavity, which causes referred C4 dermatomal shoulder pain by irritating the phrenic nerve [1, 3, 9]. By use of PRM, it will remove residual CO_2 at the end of the operation by increasing intraperitoneal pressure mechanically, which may decrease pain by allowing CO_2 to escape from the trocar port [29, 30]. Moreover, Phelps et al. conducted that PRM decreased shoulder pain severity from 61 to 31% effectively. They found that residual CO_2 gas is removed from the peritoneal cavity by PRM, which decreases intraabdominal acidosis, and irritation of the phrenic nerve, and peritoneal cavity [19].

Limitations

This study has a scope of limitation summarized in the small sample size that could restrict the statistical power and generalizability. However, this study utilized a randomized controlled study that lead to reach a standardized outcome measures. Although, the level of pain was measured in frequent times, the lack of longer-term follow-up measurmenst to provide more definitive conclusions regarding the influence of the pulmonary recruitment maneuver on post-laparoscopic shoulder pain in patients undergoing laparoscopic cholecystectomy is another study limitation.

Conclusion

It is important to note that the optimal technique, timing, and duration of the pulmonary recruitment maneuver have not been standardized across studies. Additionally, factors such as patient characteristics, surgical technique, and anesthesia management may also influence the occurrence and intensity of post-laparoscopic shoulder pain. To be concluded, the influence of the pulmonary recruitment maneuver on post-laparoscopic shoulder pain in patients undergoing laparoscopic cholecystectomy remains reduces shoulder pain. Further research is needed to establish the effectiveness of the maneuver and to determine the optimal technique and timing for its application in reducing post-laparoscopic shoulder pain.

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Declarations

Disclosures All authors agreed with the publication process and Bushra Mousa Samarah, Fatema Amer Shehada, Jamal Qaddumi, Nour Aldin Almasry, Nisser Alhroub, Bayan ALBashtawy, Khitam Mohammad, Sa'd ALBashtawy, Abdullah Alkhawaldeh, Mohammed ALBashtawy, Omar Al Omari, Ma'en Aljezawi, Shereen Hamadneh, Mohammad Suliman, Salam Bani Hani, and Zaid ALBashtawy have no conflicts of interest or financial ties to disclose.

Ethical approval This study was approved by the institutional review board of An-Najah National University before the first patient enrollment.

Informed consent Written informed consent was obtained from all patients participating in this study.

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