The Effect of Volume Controlled and Pressure Controlled Ventilation Modes on Cerebral Oximetry and Blood Gas Status in Laparoscopic Cholecystectomy, A Randomized Controlled Trial

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Abstract

Background: To compare the volume-controlled and pressure-controlled ventilation modes with near infrared spectroscopy (NIRS) cerebral oximetry and blood gas status in laparoscopic cholecystectomy

Methods: Seventy patients (n=70), who underwent elective laparoscopic cholecystectomy operation were randomized into two groups (volume control ventilation - group V, pressure control ventilation - group P). Demographic data (age, gender, body mass index) and operative data (anesthesia, surgery, and insufflation durations) were recorded. Patients' single derivation electrocardiogram, pulse oximetry, non-invasive arterial pressure, NIRS cerebral oximetry and end-tidal CO_2 parameters were recorded. Measurements were done at the start of anesthesia (T0), at the end of intubation (T1), 5 minutes after the insufflation (T2), at the time just before desufflation (T3) and 5 minutes after desufflation (T4).

The patients' heart rate, systolic and diastolic arterial pressure, saturation of pulse oximetry, and NIRS values were recorded for time points. Additionally, arterial gas results and mechanical ventilation parameters were recorded as well.

Results: No significant difference was found in age, sex, body mass index. Operation, anesthesia and insufflation durations were similar for the groups. In Group P, NIRS right T1-2-3 averages and NIRS left T2-3 averages were significantly higher than Group V (p=0.030, p=0.001, p=0.001, p=0.006, p=0.002 respectively). In Group P T1-T2-T4, mean peak pressures and mean plateau pressures were significantly lower than Group V (p=0.003, p=0.001, p<0.001, p=0.011, p=0.001, p<0.001 respectively).

Conclusion: Mechanical ventilation that performed in pressure-control ventilation mode is resulted with better tissue oxygenation than volume-control ventilation mode. In pressure-control ventilation mode, peak pressure and plateau pressure were lower.

Registration of study at ClinicalTrials.gov was made at 25/01/2021 with the NCT04723043 number.

Background

Since the laparoscopic methods have been introduced to the surgical operations, laparoscopic cholecystectomy has become the golden standard in cholelithiasis surgery.[1] For laparoscopic surgery, carbon dioxide (CO_2) insufflation is used which increase the intra-abdominal pressure. The arterial oxygenation, the functional residual capacity and the lung compliance will be affected and may be resulted with cardiovascular events.[2,3]

Volume-controlled ventilation (VCV) and pressure-controlled ventilation (PCV) are two mechanical ventilation modes that can be used along with their own advantages and disadvantages.[3] The VCV needed a pre-determined tidal volume (TV). The risk of lung damage is the main concern. In contrast the PCV avoid from excess respiratory tract pressure which applied to the lung. However TV may become unstable. Both techniques previously evaluated if one provide lower respiratory work and better tissue oxygenation. Some studies indicated that PCV is better for arterial and tissue oxygenation.[4]

Along with the arterial gas results, near infrared spectroscopy (NIRS) is used to evaluate the depth of anesthesia by measuring the oxygenation change at the tissue level in the prefrontal cortex.[5] Although NIRS was used in different surgeries, their use in laparoscopic abdominal surgery is extremely limited.[5,6] In the available literature we could not be able to find a study which evaluates the effectiveness of perioperative ventilation modes with the NIRS method.

The aim of present study was to compare VCV and PCV modes with NIRS cerebral oximetry and arterial gas results in laparoscopic cholecystectomy

Materials And Methods

A prospective, randomized study was conducted in the Sisli Hamidiye Etfal Training and Research Hospital between March and July 2020. Study was started after obtaining approval from the local ethics committee with the approval number: 1496. Registration of study at ClinicalTrials.gov was made at 25/01/2021 with the NCT04723043 number. Informed consent was taken from all patients. All procedures that performed in our study were made in accordance with the ethical standards of the Helsinki declaration (2008).

Sample size calculation and randomization

Considering the difference in large effect size (effect size=0.8) between the groups, the sample size was calculated as 70 cases in total for 95% Power, alpha significance level 0.05. Randomization was done with closed envelopes before the procedure.

Inclusion and exclusion criteria

For the study period patients that underwent elective laparoscopic cholecystectomy were enrolled for the study. Patients aged between 18 and 65, with American Society of Anesthesiology (ASA) score 1 and 2, body mass index (BMI) <30 kg / m2, were included.

Patients who did not give informed consent, patients who underwent previous thoracic/abdominal surgery, patients who underwent emergency laparoscopic cholecystectomy, patients who have ASA score ≥3, hematocrit value ≤ 30 and, BMI> 30 kg / m2 were excluded. Patients with a history of cardiac, neuromuscular, hepato-renal, endocrine, major pulmonary disease (defined as a decrease in capacity or flow rates below 70% in pulmonary function tests) were also excluded. Patients who returned to laparotomy for surgical reasons after starting laparoscopically, who developed perioperative hemodynamic instability and who used respiratory mechanics outside the study protocol were excluded from the study.

Primary-Secondary Outcomes

The primary outcomes of the study were the cerebral oxygenation measured with NIRS, peak pressure and plateau pressure of the patients in both groups, the secondary findings were the patients' SpO_2, end-tidal carbon dioxide and partial oxygen pressure in arterial blood gases.

Preoperative care

All patients underwent standard anesthesia evaluation for the procedure. Premedication was done with 0,07 mg/kg intravenous midazolam.

Intraoperative care

Single derivation electrocardiogram, pulse-oximetry, noninvasive arterial pressure and $EtCO_2$ parameters were monitored. NIRS monitoring was performed using a Masimo (Irvine, CA, USA) device. NIRS cerebral probes were placed in the right and left frontal regions. A 20-gauge cannula was inserted into the radial artery. Anesthesia induction is by intravenous administration of 2 mg/kg propofol, 1 mg/kg lidocaine, 1.5 mcg/kg fentanyl and 0.6 mg/kg rocuronium bromide. Anesthesia maintenance was done with sevoflurane %2 and remifentanil 0.15-0.25 mcg/kg/hour. During the maintenance process, the oxygen-air flow was set to 4 lit/min and the FiO_2 set to 40%. During anesthesia, mechanical ventilation was applied to the patients with a Drager (Medical, Lübeck, Germany) brand device.

Mechanical ventilation settings applied to all patients were adjusted according to ideal body weight. In the P group, inspiratory pressure (P_{insp}) was set to create a tidal volume of 8 ml / kg in pressure-controlled mode, while in the V group, the tidal volume was set as 8 ml / kg in the volume-controlled mode. In both groups, the initial respiratory frequency was 12 breaths/minutes, the inspiration/expiration time ratio was 1/2, FiO_2 was 40%, and positive end expiratory pressure (PEEP) was 5cm/H_2O. While applying mechanical ventilation in all patients, it was aimed to keep the $EtCO_2$ value between 33-35 mmHg. If the $EtCO_2$ was above 35 mmhg, the respiratory frequency was primarily increased by 2 units every five minutes in both groups. In this increase, the frequency was accepted as the upper limit of 18 breaths/minute. If the $EtCO_2$ values did not decrease under 35 mmHg at the 5th minute after reaching 18 breaths per minute, the P_{insp} value of the patients in the P group was increased by 2 cm/H2O every five minutes as needed. In the V group, the volume settings were increased by 1 ml/kg every five minutes as needed. The upper limit was determined as 30 cm/H2O for the P group and 10 ml/kg for the V group. Patients whose CO_2 values did not decrease under 35mmhg despite mechanical ventilation with all these upper limit values were excluded from the study by making more complicated changes in mechanical ventilation and insufflation pressures. If $EtCO_2$ values were below 33 mmHg, in both groups, it was first reduced to 10 breaths/min, and if there was no increase after five minutes, P_{insp} values were decreased by 2 cm/H2O every five minutes in the P group, while the tidal volume was decreased by 1 ml/kg in the V group. However, tidal volume was not allowed to fall below 6 ml/kg in both groups.

Demographic data (gender, age, height, weight, and ASA score) as well as operative data (anesthesia, operation, and insufflation duration) were recorded in both groups, T0 was defined as T0 before anesthesia, T1 after intubation, T2 5 minutes after insufflation, T3 just before desufflation, and T4 5 minutes after desufflation. Heart rate, systolic/diastolic arterial pressure values, saturation of pulse-oximetry (SpO_2) and NIRS values were recorded at all time points. Additionally, $EtCO_2$ in T1, T2, T3 and T4; arterial blood gas results for pH, pO_2, pCO_2, HCO_3, BE and Lactate; Tidal volume, respiratory frequency, peak pressure (P_{peak}), plateau pressure ($P_{plateau}$) and, PEEP was recorded.

Statistical analysis

SPSS 15.0 for Windows program was used for statistical analysis. Descriptive statistics; numbers and percentages for categorical variables, mean, standard deviation, minimum and maximum for numerical variables were given. Comparisons of numerical variables in two independent groups were made using the Student t-Test (when the normal distribution exists), the Mann Whitney U test (when the normal distribution condition was not exist). The rates in the groups were compared with Chi-Square Analysis. Statistical alpha significance level was accepted as p<0.05.

Results

CONSORT diagram of the study was presented in figure 1. In total 70 patients were evaluated in the study between March and July 2020. Groups did not differ for age, BMI, operative time, anesthesia duration and insufflation duration (p>0.05 for all comparisons) (Table 1).

Table 1
Comparison of demographic characteristics, operative time, and anesthesia duration of the patients that underwent volume controlled/pressure controlled ventilation in laparoscopic cholecystectomy

		Grup V	**Grup P**	
		n=35 (%)	n=35 (%)	p
Gender	**Male**	7 (20,0)	11 (31,4)	[b]0,274
	Female	28 (80,0)	24 (68,6)	
		Mean.±SD (Min-Max)	Ort.±SD (Min-Max)	p
Age		48,8±11,1 (27-65)	48,0±10,1 (23-65)	[a]0,753
BMI		27,1±2,3 (20-30)	26,7±3,0 (20-30)	[c]0,882
Operative time		76,0±16,8 (50-110)	77,3±19,9 (50-130)	[c]0,990
Anesthesia duration		86,0±16,8 (60-120)	87,6±20,2 (60-140)	[c]0,952
İnsufflation duration		41,4±9,4 (30-70)	40,0±11,8 (30-90)	[c]0,297

[a]Student-t Test, [b]Pearson Chi-Square Test, [c]Mann Whitney U Test, BMI:Body Mass Index

No significant difference exists in the right and left averages of T0 and T4 NIRS measurements in both groups (p=0.060 p=0.208). Mean values of NIRS at right T1-2-3 and left T2-3 of Group P were significantly higher than Group V (p=0.030 p=0.001 p=0.001 p=0.006 p=0.002 respectively) (Table 2).

Table 2
Comparison of NIRS of patients that underwent volume controlled/pressure controlled ventilation in laparoscopic cholecystectomy

		Grup V		**Grup P**		
		Mean±SD	Median (Min-Max)	Mean±SD	Median (Min-Max)	p
NIRS-Right	T0	65,5±4,8	65 (54-75)	67,7±5,0	68 (57-79)	[a]0,060
	T1	67,1±6,5	67 (52-80)	70,5±6,1	71 (58-80)	[a]**0,030***
	T2	64,8±5,9	65 (54-75)	70,1±6,4	72 (56-81)	[a]**0,001***
	T3	67,4±5,0	68 (58-77)	71,7±4,9	73 (62-82)	[a]**0,001***
	T4	68,1±4,5	69 (59-77)	70,1±5,0	70 (62-83)	[a]0,081
NIRS-Left	T0	65,0±4,6	65 (57-77)	66,5±5,5	66 (55-80)	[a]0,208
	T1	66,2±6,7	66 (54-85)	68,7±6,6	68 (55-81)	[a]0,122
	T2	64,1±6,5	63 (53-77)	68,4±6,1	69 (53-79)	[a]**0,006***
	T3	65,9±5,2	67 (55-74)	70,2±6,0	71 (56-81)	[a]**0,002***
	T4	66,7±4,9	68 (56-77)	68,7±5,6	69 (57-80)	[c]0,137

*[a]Student-t Test, [c]Mann Whitney U Test, NIRS: Near infrared spectroscopy, *p<0,05*

Hemodynamic parameters were presented in Table 3. The systolic, diastolic and, mean arterial pressures did not differ between groups (p>0.05 for all comparisons). The heart rate at T0, T2 and T3 was significantly high in group P (p=0,017 p=0,043 p=0,020 respectively). The SpO_2 levels was significantly lower in group P at T0 (p=0,006). The $EtCO_2$ levels was significantly higher in group P at T2 time point (p=0,008). Other comparisons for hemodynamic parameters were not significant. The comparisons for blood gas parameters were not significant as well (p>0.05 for all comparisons) (Table 4).

Table 3
Hemodynamic parameters of the patients that underwent volume controlled/pressure controlled ventilation in laparoscopic cholecystectomy

		Grup V		**Grup P**		
		Mean±SD	Median (Min-Max)	Mean.±SD	Median (Min-Max)	p
SAP	T0	141,5±15,1	140 (108-170)	135,4±23,7	139 (30-180)	[a]0,204
	T1	115,6±20,5	110 (90-167)	109,1±12,9	107 (90-137)	[a]0,121
	T2	118,2±18,2	120 (85-174)	119,1±18,6	116 (90-167)	[a]0,826
	T3	114,1±13,5	110 (90-149)	108,7±21,4	108 (20-151)	[c]0,206
	T4	110,0±14,4	107 (86-148)	110,2±10,9	112 (83-130)	[a]0,940
DAP	T0	82,9±13,7	81 (60-114)	82,2±9,7	85 (58-100)	[c]0,809
	T1	69,5±16,6	70 (8-110)	69,3±9,5	70 (52-86)	[a]0,930
	T2	75,4±12,0	70 (47-102)	78,3±13,6	80 (50-106)	[a]0,356
	T3	69,2±11,4	69 (49-102)	67,8±12,5	66 (45-91)	[a]0,612
	T4	67,1±11,1	67 (50-90)	67,5±8,7	68 (50-80)	[a]0,886
MAP	T0	107,1±11,8	105 (80-132)	104,2±11,8	106 (79-128)	[a]0,311
	T1	89,9±15,2	86 (68-132)	86,3±9,5	86 (71-106)	[a]0,240
	T2	90,5±12,6	91 (64-112)	95,1±15,4	94 (70-132)	[a]0,181
	T3	88,2±11,8	85 (73-123)	86,8±12,7	86 (68-118)	[c]0,724
	T4	86,1±13,2	85 (65-123)	86,5±10,1	89 (62-103)	[a]0,879
HR	T0	76,5±11,2	76 (61-100)	84,2±14,8	85 (54-120)	[a]**0,017***
	T1	77,9±12,2	80 (57-100)	82,8±14,2	81 (63-120)	[a]0,125
	T2	68,3±10,7	69 (50-88)	74,6±14,7	72 (50-119)	[a]**0,043***
	T3	62,2±10,0	61 (45-90)	68,0±10,4	69 (49-96)	[a]**0,020***
	T4	65,3±12,3	64 (50-108)	62,7±10,7	60 (45-87)	[c]0,424

*[a]Student-t Test, [c]Mann Whitney U Test, *p<0,05, SAP: Systolic arterieal pressure, DAP: Diastolic arterial pressure, MAP: Mean arterial pressure, HR: Heart Rare, ETCO$_2$: End Tidal CO$_2$*

		Grup V		Grup P		
SPO_2	T0	98,5±1,3	99 (95-100)	98,7±1,3	99 (96-100)	[c]0,456
	T1	99,1±0,9	99 (97-100)	98,4±1,0	98 (96-100)	[c]**0,006***
	T2	98,4±2,6	99 (85-100)	98,3±1,5	98 (93-100)	[c]0,314
	T3	98,8±1,1	99 (97-100)	98,7±1,2	99 (96-100)	[c]0,710
	T4	99,2±0,9	99 (97-100)	98,7±1,1	99 (96-100)	[c]0,113
$ETCO_2$	T1	32,2±2,4	32 (27-36)	32,6±1,7	33 (28-35)	[c]0,454
	T2	33,1±2,8	33 (25-40)	34,5±1,7	35 (29-38)	[c]**0,008***
	T3	34,5±1,3	35 (32-38)	34,0±2,6	34 (26-43)	[c]0,194
	T4	33,6±1,8	34 (29-38)	33,5±1,6	34 (30-38)	[c]0,692

*[a]Student-t Test, [c]Mann Whitney U Test, *p<0,05, SAP: Systolic arterieal pressure, DAP: Diastolic arterial pressure, MAP: Mean arterial pressure, HR: Heart Rare, $ETCO_2$: End Tidal CO_2*

Table 4
Blood gas parameters of the patients that underwent volume controlled/pressure controlled ventilation in laparoscopic cholecystectomy

		Grup V		Grup P		
		Mean .±SD	Median (Min-Max)	Ort.±SD	Median (Min-Max)	p
PH	T1	7,45±0,04	7,45 (7,38-7,52)	7,43±0,04	7,43 (7,33-7,49)	[a]0,118
	T2	7,41±0,04	7,41 (7,33-7,49)	7,40±0,04	7,41 (7,3-7,46)	[a]0,273
	T3	7,40±0,04	7,40 (7,33-7,50)	7,41±0,04	7,42 (7,3-7,49)	[c]0,285
	T4	7,39±0,04	7,38 (7,31-7,47)	7,40±0,04	7,41 (7,3-7,49)	[a]0,161
PO_2	T1	157,2±26,6	150 (118-220)	159,7±32,9	160 (90-220)	[a]0,730
	T2	140,3±27,4	138 (95-190)	144,9±30,5	140 (95-200)	[c]0,510
	T3	142,4±34,0	140 (90-263)	151,7±25,3	150 (109-210)	[a]0,195
	T4	163,2±44,2	150 (107-355)	161,0±30,5	150 (115-260)	[c]0,750
	T4	-0,15±1,68	0,2 (-4-2,6)	-0,73±1,95	-0,8 (-5,3-2,7)	[c]0,172
PCO_2	T1	35,1±2,9	35 (30-40)	35,8±2,1	36 (32-41)	[c]0,280
	T2	37,7±2,8	38 (32-43)	38,2±1,9	38 (34-41)	[a]0,503
	T3	38,3±2,9	38 (32,6-43)	37,3±2,5	38 (30-43)	[c]0,166
	T4	38,9±4,1	38 (34-53)	37,1±2,4	37 (32-42)	[c]0,116
HCO_3	T1	24,9±1,8	25,5 (20-27,6)	24,3±1,7	25 (18-26,6)	[c]0,111
	T2	24,3±2,0	25 (20-27,5)	23,9±1,6	24 (20-26,8)	[c]0,124
	T3	24,1±1,9	25 (20-27)	23,6±1,8	24 (20-27,4)	[c]0,083
	T4	24,0±1,6	24 (21-26,2)	23,6±1,8	24 (20-26,9)	[c]0,284
BE	T1	0,71±1,82	1,5 (-3,4-3,6)	0,04±1,89	0,5 (-7-2,5)	[c]0,052
	T2	0,20±1,96	0,9 (-4-3,4)	-0,47±1,84	-0,2 (-5,5-2,4)	[c]0,071
	T3	0,03±1,84	0,5 (-4-2,9)	-0,57±2,11	-0,3 (-5,5-3,3)	[c]0,115
	T4	-0,15±1,68	0,2 (-4-2,6)	-0,73±1,95	-0,8 (-5,3-2,7)	[c]0,172

[a] *Student-t Test*, [c] *Mann Whitney U Test, mmol/L: millimole/liter*

		Grup V		Grup P		
Lactate	T1	1,30±0,46	1,1 (0,6-2,3)	1,27±0,63	1,2 (0,4-2,8)	[c]0,432
(mmol/L)	T2	1,51±0,57	1,4 (0,8-2,6)	1,49±0,65	1,2 (0,7-3,1)	[c]0,786
	T3	1,53±0,69	1,3 (0,5-3,5)	1,47±0,55	1,3 (0,7-3,1)	[c]0,934
	T4	1,41±0,59	1,3 (0,5-3)	1,37±0,64	1,2 (0,5-3,2)	[c]0,736

[a]Student-t Test, *[c]Mann Whitney U Test, mmol/L: millimole/liter*

For ventilation parameters, P_{peak} and $P_{plateau}$ levels in T1, T2 and T4 were significantly lower in group P (p=0,003 p=0,001 p<0,001 p=0,011 p=0,001 p<0,001 respectively). The TV at T3 was significantly high in group P (p=0,017). Other comparisons for ventilation parameters were not significant (p>0.05 for all comparisons) (Table 5).

Table 5
Ventilation parameters that underwent volume controlled/pressure controlled ventilation in laparoscopic cholecystectomy

		Grup V		Grup P		
		Ort.±SD	Median (Min-Maks)	Ort.±SD	Median (Min-Maks)	p
P_{peak}	T1	16,9±2,9	17 (13-26)	15,0±2,1	15 (11-19)	^{c}**0,003***
	T2	23,1±3,8	24 (16-33)	20,3±2,7	21 (15-25)	^{a}**0,001***
	T3	21,6±3,7	21 (15-31)	20,0±3,2	20 (14-25)	^{a}0,053
	T4	18,8±2,7	19 (14-27)	15,3±2,1	16 (11-20)	^{c}**<0,001****
$P_{plateau}$	T1	16,3±2,6	16 (12-24)	14,8±2,0	15 (11-19)	^{a}**0,011***
	T2	22,5±3,6	23 (16-30)	19,9±2,5	20 (15-25)	^{a}**0,001***
	T3	20,8±3,7	20 (15-30)	19,5±3,1	20 (14-25)	^{c}0,129
	T4	17,8±2,5	18 (14-25)	15,0±2,2	15 (11-20)	^{a} **<0,001***
TV	T1	472,3±38,0	500 (400-550)	492,5±61,9	500 (400-650)	^{c}0,244
	T2	470,3±37,5	450 (400-550)	482,4±65,0	500 (380-600)	^{c}0,380
	T3	470,6±39,9	480 (400-550)	508,4±70,7	500 (400-650)	^{c}**0,017***
	T4	470,9±37,8	450 (400-550)	486,1±64,5	480 (400-650)	^{c}0,744
f	T1	11,7±0,8	12 (10-14)	11,5±1,0	12 (10-14)	^{c}0,383
	T2	12,2±1,6	12 (10-16)	12,3±1,3	12 (10-16)	^{c}0,774
	T3	13,3±1,5	14 (10-16)	12,9±1,1	12 (10-14)	^{c}0,161
	T4	13,2±1,5	12 (10-16)	12,2±0,8	12 (10-14)	^{c}0,078

*^{a}Student-t Test, ^{c}Mann Whitney U Test, *p<0,05 **p<0,01, TV: Tidal Volume, f: frequency*

Discussion

In a randomized controlled setting, our results indicate that cerebral oxygenation was better in patients ventilated with PCV mode due to higher NIRS values and lower P_{peak} and $P_{plateau}$ values.

The laparoscopic surgery improves the quality of life by avoiding abdominal incisions, extensive dissection and related comorbidities.[1] However pneumoperitoneum causes an increase in intra-abdominal pressure and indirectly a decrease in lung volumes, functional residual capacity and pulmonary compliance. An increase in airway resistance may be resulted with development of atelectasis in the basal parts of the lung and ventilation-perfusion mismatch can occur.[1,3] The VCV mode increases P_{peak} and $P_{plateau}$ values which are directly related with the lung damage. In a randomized controlled setting, Sen et al. compared VCV and PCV on 40 patients who underwent laparoscopic cholecystectomy. The results indicate that P_{peak} and $P_{plateau}$ pressures were higher in patients who underwent VCV after pneumoperitoneum.[7] Netthra et al. compared VCV and PCV on 60 laparoscopic cholecystectomy patients. Their results indicate that PCV resulted with lower P mean and Ppeak values. Our study is also consistent with the studies which resulted in favor of PCV in laparoscopic cholecystectomy. Our results indicate that P_{peak} and $P_{plateau}$ values were found to be significantly higher in the VCV group, especially after insufflation. Literary data indicate that VCV may decrease the safety index by increasing the risk of volu-trauma and barotrauma in the VCV mode in laparoscopic cases. To stop the increase in P_{peak} pressure and decrease lung injury, applications such as changing the respiratory rate and tidal volume or switching to PCV mode are performed.[9] Although the PCV mode is a good method in the management of elevated P_{peak} values, its effects on ventilation dynamics and hemodynamic parameters did not clearly define.

The high P_{peak} values in VCV mode may also resulted with decrease in partial oxygen pressure. However, the effect of VCV and PCV modes on tissue oxygenation are contradictory. Balick-Weber et al. examined the respiratory effects of laparoscopic surgery on 21 patients. No change was shown on partial oxygen pressures after insufflation.[10] Hans et al. also reported no significant difference between PO2 pressures on 40 obese patients who underwent laparoscopic by-pass operation.[11] However, in two other studies conducted in obese patients, partial oxygen pressures were shown to be higher in patients ventilated with PCV mode.[12,13] In our study, partial oxygen pressure values were higher in PCV mode, however no significant difference was found for blood gas parameters between groups.

Tissue oxygenation measurements have been used frequently in perioperative patient management in recent years. Different methods such as bispectral index electroencephalography or auditory evoke potentials are used to measure anesthetic depth. The NIRS is another method which used to evaluate the depth of anesthesia by measuring the oxygenation change at the tissue level in the prefrontal cortex.[14] We could not be able to find a study that evaluates the cerebral oxygenation with NIRS in laparoscopic surgery. However, NIRS was used in different surgeries previously.

Green et al. [6] in their study with 46 patients who underwent major abdominal surgery, detected low tissue oxygenation using the NIRS method, which could not be detected by conventional monitoring methods. Gibson et al.[15] compared NIRS values before and after insufflation in 70 patients who had undergone laparoscopic abdominal surgery and showed that NIRS values decreased statistically after insufflation. Although there was no significant difference between SpO_2 and PaO_2 pressures in our study, the NIRS values of patients who underwent PCV were found to be significantly higher during pneumoperitoneum compared to the VCV group. This may be an evidence that oxygenation disorder occurs at the tissue level, although the resulting oxygenation change is not reflected in conventional monitoring parameters and arterial blood gas analysis.

Kurukahvecioğlu et al.[16] in their study with 60 patients who had undergone laparoscopic abdominal surgery showed that insufflation pressure caused blood to pool in the lower extremities, which decreased cerebral NIRS values. This decrease is a mechanical result of the high pressure created by insufflation in the abdomen. This mechanical condition occurs not only in the abdomen, but also in the thorax, with the high P_{peak} created by the VCV mode, as demonstrated in our study. Increased intrathoracic pressure reduces preload and indirectly cardiac output, and consequently explains the significantly lower NIRS values in the VCV group in our study.

The limitation of our study is that we had to use P_{peak} and $P_{plateau}$ instead of trans-pulmonary pressure to evaluate the safety of controlled mechanical ventilation modes. Because transpulmonary pressure is the most objective parameter in the evaluation of ventilator induced lung injuries. However, it was not preferred because it is measured by invasive methods.

Conclusion

In laparoscopic cholecystectomy operations, tissue oxygenation with PCV mode is higher than with VCV mode. In PCV mode, the risk of lung barotrauma, which is likely due to high P_{peak} and $P_{plateau}$ values, is lower. NIRS can be used in laparoscopic cholecystectomy cases because it is more sensitive, non-invasive and easy to use than arterial blood gas analysis in measuring tissue oxygenation.

Abbreviations

NIRS: near infrared spectroscopy

VCV: Volume-controlled ventilation

PCV: pressure-controlled ventilation

TV: Tidal volume

ASA: American Society of Anesthesiology

BMI: body mass index

P_{insp}: inspiratory pressure

P_{peak}: peak pressure

$P_{plateau}$: plateau pressure

PEEP: positive end expiratory pressure

Declarations

Ethics and Consent to participate: Informed consent was taken from all patients. All procedures that performed in our study were made in accordance with the ethical standards of the Helsinki declaration (2008). This clinical study was approved by Sisli Hamidiye Etfal Training and Research Hospital Ethics Committee with the number 1496 on 02/06/2020.

Consent for publication: Not applicable

Availability of data and materials: The datasets used and/or analysed during the current study available from the corresponding author on reasonable request.

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Author's contributions: Emre Badur, Mustafa Altınay, Leyla Türkoğlu and A. Surhan Çınar conceived and designed the study. Emre Badur, Mustafa Altınay, Pınar Sayın, Tuğba Yücel and Leyla Türkoğlu carried out the study protocol and retrospectively performed data collection. Emre Badur, Mustafa Altınay, and Pınar Sayın performed statistical analysis and data interpretation. All authors contributed to the writing of and approved the final manuscript.

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Figures

CONSORT 2010 Flow Diagram

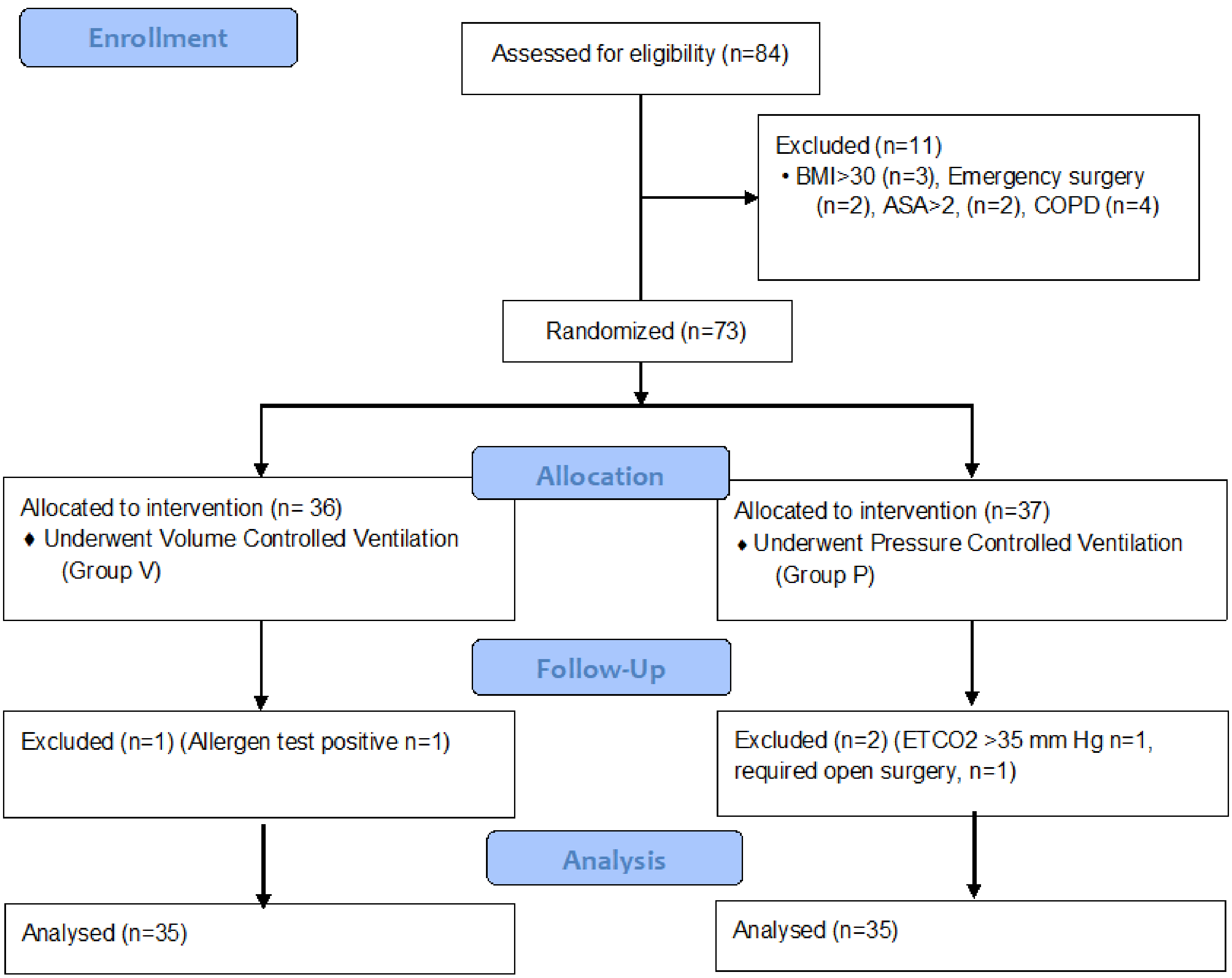

Figure 1

CONSORT diagram of the study that evaluates the effect of of Volume Controlled and Pressure Controlled Ventilation Modes on Cerebral Oxymetry and Blood Gas Status in Laparoscopıc Cholecystectomy