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Comparing the ratio of respiratory dead space volume to tidal volume in supine and prone positions in patients under general anesthesia

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Abstract

Introduction: The prone position in the surgery room provides the surgeon with access to the area of surgery in various types of surgeries. The effects of prone position on respiratory gas exchanges are complex. **Methods:** This prospective cohort study was performed on 61 patients undergoing general anesthesia in prone and supine positions. Half an hour after intubation, 2 hours after anesthesia and before extubation in recovery, arterial blood gas changes, ETCO2, respiratory dead space volume to tidal volume ratio (VD / VT), and hemoglobin levels in both groups were measured and recorded. **Findings:** Sixty one patients (29 patients in supine and 32 patients in prone positions) were evaluated. There was no significant relationship between VD/VT ratio during anesthesia between the two groups (P = 0.16). In examining this ratio at different measurement times, the results showed that only in supine group, VD / VT relationship was statistically significant two hours after anesthesia onset and at the end of anesthesia (P=0.01). There were no significant differences in pH, PCO2, PECO2, Ppeak and PaO_2 in the two groups at different time points. Hb levels were statistically significant in both groups at different time points; but the difference between the two groups was not significant. **Conclusion**: The ratio of respiratory dead space volume to tidal volume and oxygenation in the prone position compared to supine position was not changed in patients undergoing general anesthesia with mechanical ventilation. The process of oxygenation changes in the prone position has improved over time.

Keywords: respiratory dead space, tidal volume, supine position, prone position

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INTRODUCTION

Advances in surgical maneuvers and monitoring devices have increased the number of clinical applicable positions such as supine, prone and lateral positions. Supine and prone are two positions used in most surgeries (Zhang et al. 2017). Prone position is used to facilitate procedures in spine and other neurosurgical surgeries (Edgcombe et al. 2008, Kwee et al. 2015, Landi et al. 2013, St-Arnaud and Paquin 2008, Soro et al. 2007) On the other hand, respiratory function of patients during anesthesia in the surgery room is one of the most important issues that anesthesiologists face (Zhang et al. 2017). Establishing an appropriate position will allow for a good communication between the anesthesiologist and the surgeon (Knight and Mahajan 2004). There are many debates about the advantages and disadvantages of supine and prone positions, especially in respiratory diseases (Zhang et al. 2017, Kwee et al. 2015, Welch et al. 2015).

The respiratory system compliance response to the prone position is diverse and complex (Hu et al. 2014) 19 Most people believe that prone position is a non-physiological condition that decreases compliance, pulmonary oxygenation and increases atelectasis. While improvements in respiratory dynamics changes in the prone position have been reported in studies (Zhang et al. 2017). Prone position has been shown to be a relatively simple method for improving gas exchange and oxygenation in ARDS patients (Tang et al. 2012, Cornejo et al. 2013, agui and Beppu 2007, Mezidi et al. 2018, Reutershan et al. 2006).

Several mechanisms have been proposed to explain these effects: 1. Improved regional ventilation 2. Redistribution of perfusion which is essentially related to

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horizontal axis 3. Greater homogeneity of ventilation to perfusion ratio (V / Q matching) 4. Recruitment of perfused tissues (Reutershan et al. 2006). Prone positioning also results in increased lung volume and alveoli involved due to diaphragm movement (Reutershan et al. 2006, Koulouras et al. 2016). However, over the past few years, there have been no significant changes in ARDS mortality rates despite improved oxygenation (Tang et al. 2012, Cornejo et al. 2013).

The prone position is faced with various complications resulting from the increase in pressure in the anterior structures. The incidence of pressure ulcers during surgery was reported to be 5-66%.6 In addition, as the abdominal contents are displaced, intra-abdominal pressure increases and leads to inferior vena cava (IVC) compression and decreased cardiac output (Knight and Mahajan 2004, Hu et al. 2014, Reutershan et al. 2006). Many of the physiological changes that occur in the prone position can be mitigated by increasing accuracy in changing the position and avoiding pressure on the abdomen. Safe use of this position requires understanding of these changes and complications (Edgcombe et al. 2008, Knight and Mahajan 2004).

On the other hand, prone position may result in a uniform distribution of pressure in the lung, resulting in improved adaptation of ventilation to regional perfusion V / Q in the lung, and improvement in chest wall mechanics (Reutershan et al. 2006, Dalmedico et al. 2017, Jahani et al. 2018).

In healthy subjects under general anesthesia in prone position, the functional residual capacity (FRC) was measured to be 2.45 liters, which is higher than that of supine position (Reutershan et al. 2006). Prone position causes the lung to fit into the chest wall against gravitational force and reduces lung compression to some extent (Reutershan et al. 2006).

In patients under general anesthesia, in the prone position, the lungs expand better and oxygenation improves (Palmese et al. 2014, Intagliata et al. 2019). A few studies have been performed to evaluate the function of pulmonary ventilation in patients undergoing mechanical ventilation in general anesthesia (Zhang et al. 2017). The aim of this study was to compare gas exchange and volume ratio of respiratory dead space volume to tidal volume in supine and prone positions in patients under general anesthesia.

METHOD

This study was conducted after obtaining informed consent from study participants. The study was performed from 4.4.2018 to 4.4.2019as a cohort prospective study on 32 patients undergoing spinal canal stenosis surgeries, PSF surgery in prone position, and 29 patients undergoing upper and lower limb fracture surgeries in supine position. All patients underwent TIVA (Total Intravenous Anesthesia).Sampling method was available sampling.

Inclusion criteria included 18-75 years old patients, ASA CLASS I, II, 2-4 hours surgery under general anesthesia, not being pregnant, not being a smoker, no respiratory diseases and infections, bronchiolitis at four weeks before study. Exclusion criteria included any changes in the patient's body position during anesthesia, cardiopulmonary resuscitation, prone position intolerance during the study, and duration of surgery less than 2 hours and more than 4 hours.

All patients underwent cardiopulmonary monitoring by (saadat alborz B5), 1-oximeter pulse (saadat alborz B5), and Peco2 capnography (MASIMO). Age, sex and the duration of surgery were recorded. Hemoglobin, Arterial Blood Gases, peak, VD / VT ratio (respiratory dead space volume to tidal volume), PetCO2, half an hour after intubation (T1), 2 hours after anesthesia (T2) and before extubation (T3) was measured and recorded. The difference between PaCO2 and PetCO2 was calculated as an indicator of the respiratory dead space volume 11. The VD / VT ratio was calculated using the Bohr formula (Charron et al. 2011).

$$VD/VT = (PaCO2 - PetCO2)/PaCO2$$

All patients were taken an intravenous line for injecting drugs and fluids. After the Allen test was negative, the arterial line radial artery was used for blood pressure invasive monitoring and for obtaining blood samples for ABG. The anesthesia protocol was administered in both groups as: induction phase: propofol 2mg, fentanyl 3mg / kg, and 0.2mg / kg cis atracurium and in the maintenance phase: propofol 100 μ /kg/min and 2mg of cis atracurium was administered every 30 minutes. After muscle relaxation, endotracheal intubation was performed with endotracheal tube diameter of 7.5 mm for women and 8 mm for men under direct laryngoscopy. All patients were connected to a ventilator device (DRAGER FABIUS) in a volume-controlled fashion with the following specifications:

Tidal Volume: 7 ml/kg
Respiratory Rate: 12/min
Inspiration to Expiration ratio: 1:2
Peak Inspiration Pressure (PIP): 20-25 cmH_2O
PEEP: 5 cmH_2O

Post-induction position changes in the prone group were performed with above chest and abdominal support with a roll to release abdominal movements. It was put in neutral position by placing head on a horseshoe pillow. With auscultation on both sides, the correct place of endotracheal tube was ensured and the patients were at their best position with regard to airway pressure. In the Supine group, no change was needed. At the end of surgery, patients were reversed, extubation was done, and they transferred to the recovery ward. All

Table 1. Age, sex, smoking and body mass index in the two study groups

Group	N	Sex ratio (Male/Female)	Age (years)	BMI (kg/m2)	Smoker N (%)
Supine	32	16/16	51 ± 10	28.6 ± 6.9	27(93.1)
Prone	29	13/16	56 ± 12	28.7 ± 4.3	26(81.3)
P		0.68	0.08	0.97	0.162

hemodynamic parameters (heart rate, blood pressure and ECG) were within normal range.

Data were analyzed using SPSS 16 software. All measurements were reported with mean and standard deviation. The difference between the two measurements was expressed with 95% confidence interval. One-way ANOVA, Bonferroni post hoc tests, paired t-test and chi-square test were used.

FINDINGS

Table 1 shows the profile of study participants. These results show that both groups were similar in terms of age, sex, body mass index and smoking habit.

The relationship between the duration of surgery and supine and prone positions was statistically significant, the mean duration of surgery in the prone group was 4.97± 1.53 hours and in the supine group was2.66± 0.86. The results of **Table 2** show that VD / VT ratio was not statistically significant in both prone and supine positions (P = 0.169). In the supine group, this ratio was significant at different time points (T1, T2, and T3). However, this ratio was not significant in the prone group over time (P = 0.87). Also, the difference between the mean VD / VT ratio was statistically significant only at T2 and T3 at different stages of measurement (P = 0.03).

The mean pH was not significant in the supine and prone groups (P = 0.75) but in the prone group the pH changed significantly over time (P = 0.001). There was no statistically significant difference in mean pH at measurement times (T1, T2, and T3) between supine and prone groups.

No significant difference was observed in the case of PaCO2, PetCO2 and Ppeak between the two study groups (P = 0.16, P = 0.71 and P = 0.65, respectively). Also, the difference between the mean values at different measurement times in the two groups was not significant.

PaO2 in both groups was not significant like other respiratory parameters; but in the prone group, this has significantly increased over time (P = 0.01). The mean difference at different measurement times was also not significant.

Hemoglobin analysis showed no significant difference between supine and prone groups; but hemoglobin level was statistically significant in both groups (P = 0.001 and P = 0.002, respectively).

Table 3 shows the dual comparisons between the measurement times of the variables. The Bonferroni test showed that in the prone VD / VT group the comparison of all three measurement times was not significant; but in the supine group this ratio was significant when comparing T2 with T3.

Table 2. Comparison of respiratory parameters and hemoglobin in the two study groups at different time points

	Prone			P (time)		Supine			P (time)
	T_1	T_2	T_3			T_1	T_2	T_3	
VD/VT	0.17±0.6	0.17±0.49	0.17±0.63	0.87		0.16±0.05	0.14±0.04	0.17±0.05	0.02
P (type of position)					**0.16**				
$ETCO_2$	30±5	31±5	31±4	0.65		31±3	34±4	31±3	0.24
P (type of position)					**0.71**				
PH	7.43±0.05	7.39±0.05	7.38±0.04	0.001		7.42±0.04	7.40±0.03	7.41±0.08	0.33
P (type of position)					**0.75**				
$Paco_2$	37.78±6.7	37.19±6.25	37.53±5.97	0.65		36.86±5.09	36.62±5.70	35.97±4.17	0.33
P (type of position)					**0.16**				
Pao_2	302±88	268±69	280±78	0.01		316±71	303±60	302±58	0.17
P (type of position)					**0.17**				
P peak	22±4	22±4	22±4	0.33		22±3	21±4	22±4	0.34
P (type of position)					**0.65**				
Hb	12.9±1.9	12±1.8	12.1±1.2	0.001		12.5±1.9	11.8±3	11.5±1.6	0.001
P (type of position)					**0.35**				

Table 3. Dual comparisons of respiratory parameters and hemoglobin in the Supine and Prone groups

Study group	Variable	First Comparable Time	Second Comparable Time	The Two Times Mean Difference	P*
Prone	VD/VT	T_1	T_2	.003±0.009	1.000
			T_3	.001±.011	1.000
		T_2	T_3	-.003±.006	1.000
	PH	T_1	T_2	.035±.008	**<0.001**
			T_3	.045±.010	**<0.001**
		T_2	T_3	.010±.006	.352
	PaCo2	T_1	T_2	-.406±.900	1.000
			T_3	-.750±.950	1.000
		T_2	T_3	-.344±.698	1.000
	Pao2	T_1	T_2	33.719±11.550	**.019**
			T_3	22.156±11.229	.172
		T_2	T_3	-11.563±7.257	.364
	PETCo2	T_1	T_2	-.469±.789	1.000
			T_3	-.594±.758	1.000
		T_2	T_3	-.125±.576	1.000
	Hb	T_1	T_2	.913±.283	**.009**
			T_3	.725±.267	**.032**
		T_2	T_3	-.188±.212	1.000
Supine	VD/VT	T_1	T_2	.013±.008	.397
			T_3	-.012±.010	.741
		T_2	T_3	-.025±.008	**.010**
	PH	T_1	T_2	.020±.007	**.032**
			T_3	.009±.017	1.000
		T_2	T_3	-.011±.015	1.000
	PaCo2	T_1	T_2	.241±.591	1.000
			T_3	.897±.652	.539
		T_2	T_3	.655±.622	.904
	Pao2	T_1	T_2	13.621±9.618	.503
			T_3	13.966±9.511	.459
		T_2	T_3	.345±3.895	1.000
	PETCo2	T_1	T_2	-.034±.588	1.000
			T_3	.759±.538	.509
		T_2	T_3	.793±.439	.245
	Hb	T_1	T_2	.690±.183	**.002**
			T_3	1.041±.196	**<0.001**
		T_2	T_3	.352±.135	**.044**

Bonferroni test *
T1: Half an hour after intubation
T2: 2 hours after anesthesia
T3: Before extubation

DISCUSSION

The purpose of this study was to determine the effect of body position on respiratory function in patients under general anesthesia and mechanical ventilation. In general, the results of this study showed that the ratio of dead space volume to tidal volume did not differ significantly between prone and supine positions.

There was no significant difference in VD / VT ratio between the two groups. In the supine group, VD / VT ratio changes was significant. This ratio has increased over time but no increase was observed in the prone group over time. Also, in our study PaCO2 was not significantly different between the two groups at different time points. In the study of Charron et al. which performed on 13 patients with PaO2 / FiO2ratio <100 mmHg, oxygenation status and VD / VT and PaCO2 ratios in supine position and 3, 6, 9, 12 and 15 h after being in prone position were measured. The results of this study showed that PaCO2 and VD / VT ratio decreased in the prone position and the maximum changes occurred after 6 to 9 hours (Casati et al. 1997). In the Soro et al. Study, physiological and alveolar dead space volume in patients undergoing general anesthesia after 3 hours did not change significantly comparing to the prone position, which was consistent with our study (Soro et al. 2007). On the other hand, in the Palmese study, the VD / VT ratio was also significantly higher in both supine and prone positions (Intagliata et al. 2019). This difference may be due to differences in the timing of respiratory parameters measurements. As in the Palmese study, measurements were made at shorter times (30 and 90 minutes after being in the prone position). Studies by Casati and Wahba also found a 10% increase in the dead space volume within 20 minutes after prone positioning. They attributed this increase to the intrapulmonary distribution of blood flow and alveolar gas (Wahba et al. 1998, Bassampour et al. 2008). Given that the respiratory effects of prone position are related to duration of this condition (Tang et al. 2012, Koulouras et al. 2016), this discrepancy of results is expected in studies.

There is no consensus regarding the appropriate duration for respiratory efficacy of the prone position. What is agreed in most studies is that in the first two hours after being placed in the prone position, the maximal effects of this position on oxygenation improvement are observed and in the next four hours there is a slight increase in oxygenation (Santini et al.

2015). Numerous studies have shown that even redistribution of blood flow to the alveoli and areas of the lung that were reduced because of gravity and diaphragm shifts improves the ventilation to perfusion ratio in the prone position (Edgcombe et al. 2008, Dalmedico et al. 2017, Robak et al. 2011, Kozier and Erb 2004).

There was no statistically significant difference in oxygenation rate between the two groups; but in the prone group, oxygenation has improved over time. PaO2 levels during surgery were significantly increased compared to the beginning of surgery in the prone group. In a study by Keizer et al. results showed that 30 minutes after putting patients with ARDS in prone position, in 80% of patients PaO2 increased by 20 mmHg and a significant difference was observed compared to the base PaO2 value (Haddam et al. 2016).

A study by Bassampour et al on 36 ARDS patients undergoing mechanical ventilation showed that oxygenation improved significantly during 30 and 120 minutes after being placed in a prone position indicating the beneficial effects of this position on improving oxygenation in this group of patients (Santini et al. 2015). In the study of Hamddam et al., 51 patients were placed on prone position for one hour and then they were placed on supine position and oxygenation was assessed in four stages; one hour before and one hour after placement in both prone and supine positions. The results showed that one hour of patient placement in the prone position did not change the oxygenation status. Similar studies have shown that the rate of oxygenation has improved over time in the prone position (Intagliata et al. 2018, Zhang et al. 2017). In Soro et al.'s study, as in our study, there was no significant difference between the two positions of prone and supine (Soro et al. 2007).

In the present study, Paco2 levels were not significantly different in both supine and prone positions. In the Soro et al. Study, there was no significant difference between Paco2 in the supine group and at 30, 60, and 120 minutes after being placed in the prone position (Soro et al. 2007). This result was also observed in previous studies (Intagliata et al. 2018, Zhang et al. 2017). In addition, there was no significant difference in the mean peak in the prone group versus prone position (Soro et al. 2007). This may indicate that the pulmonary compliance did not differ significantly between the two groups during anesthesia.

CONCLUSION

The results of our study showed that the ratio of respiratory dead space volume to tidal volume in the prone position compared to supine position did not change in patients undergoing general anesthesia and mechanical ventilation. Also, there was no difference in oxygenation in the two positions of prone and supine; but in the prone group, the process of oxygenation changes has improved over time and the trend of changes in the ratio of the respiratory dead space volume to tidal volume remained unchanged.

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