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Effect of Change in Newborn's Position during Mechanical Ventilation on Oxygenation

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ABSTRACT
Background: Acute respiratory failure remains an important cause of morbidity and mortality in children. In the last few years great attention was paid to the effect of changes in infant's position other than the supine position during mechanicall ventilation.
Objective: To evaluate the effect of position change on oxygenation in newborn infants during mechanical ventilation in neonatal intensive care unit (NICU).
Methods: This study was across- section study, which was done on 74 obese children aged 6-18 years. This study was done at Pediatrics Department, Zagazig University Hospitals, during the period from 2017 to 2018. The cases were divided into two groups, group A included newborn infants using ventilators in supine position (supine group) and group B included newborn infants in supine position alternating with prone position (alternate group). All children were subjected to history talking and clinical examination. Anthropometric measurements were measured. In addition, carotid intima-media thickness quantification was estimated.
Results: There were statistically significant decrease in VT (ml) at (8 hr and 16 hr) among alternate group than supine group. In addition, OI and PaO_2, at 8 and 16 h in alternate position groups were higher than those in supine position group were. There were statistically significant decrease in PEEP (cm H_2O) at 8 hour among supine group than alternate group. There was no statistically significant difference between supine group and alternate group regarding PEEP (cm H_2O) at 16 hour. This study showed that, There were statistically significant decrease in PaO_2 (mm Hg) at (8 hr and 1 hr drawl) among supine group than alternate group. There was no statistically significant difference between supine group and alternate group regarding PaO_2 (mm Hg) at 16 hr.
Conclusion: Oxygenation and respiratory mechanics were significantly improved in prone position group than those in supine position group. The physiological basis of prone positioning seems to act beneficially improving hemodynamics, gas exchange and respiratory mechanics.
Keywords: Newborn's Position - Mechanical ventilation-Oxygenation.

INTRODUCTION
Acute respiratory failure remains an important cause of morbidity and mortality in children. Cardiac arrests in children frequently result from respiratory failure. In 2014, data from the National Center for Health Statistics listed respiratory illnesses as one of the top 10 causes of pediatric mortality [(1)]. The introduction of mechanical ventilation in the 1960s was one of the major new interventions in neonatology, which provided lifesaving support for infants with respiratory failure [(2)].
In the last few years, great attention was paid to the effect of changes in infant's position other than the supine position during mechanicall ventilation [(3)]. Prone positioning has been shown to improve oxygenation in extremely low-birth infants with chronic lung disease and in neonates with respiratory failure [(4)].

AIM OF THE WORK
This study aimed to evaluate the effect of position change on oxygenation in newborn infants during mechanical ventilation in NICU.

PATIENTS AND METHODS
Present study was an experimental study, which carried out on all neonates (in first 28 days of life) admitted to neonatal intensive care unit (NICU) at Zagazig University Hospital. The study was comparative study between two groups where cases selected randomly. Group A included newborn infants using ventilators in supine position and group B included newborn infants in supine position alternating with prone position.

- **Inclusion criteria:** Newborn infants with confirmed respiratory failure.
- **Exclusion criteria:** Neonates with severe chest deformities, intolerance to prone position, increased intracranial tension, acute haemorrhage and pneumothorax or hemodynamically unstable.
- **Sample Size:**

Assuming that PaO_2 in supine group after 8 hours was 60.13 ± 8.95 in supine group and 65.29 ± 7.62 in alternate group at confidence level 95% , power 80% so, total sample size is 82 (41 in each group).

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Ethical approval:

Approval was taken from the Institutional Review Board (IRB) of Faculty of Medicine, Zagazig University.

* Written informed consent was obtained from all patients or caregiver.

* All the participating patients were subjected to the following:

History: Complete history taking including sex, age and birth weight.

Examination: Respiratory distress, difficult breathing and lethargy**.**

Data collected 8 and 16 hours in both groups included ventilator parameters (FiO_2, PIP, PEEP, RR), lung mechanics [tidal volume (VT), minute ventilation (VM), partial oxygen tension (PaO_2) and partial carbon dioxide tension ($PaCO_2$)] and Oxygenation Index OI (OI=(PaO_2 x FiO_2/mean airway pressure) x 100).

Mechanical ventilation withdrawal time, PaO_2, and $PaCO_2$ at 1 hour after draw.

Investigation: Laboratory investigations included CBC and CRP.

Statistical analysis

The data were coded, entered and processed on computer using SPSS (version 18). The results were represented in tabular and diagrammatic forms then interpreted. Mean, standard deviation, range, frequency, and percentage were use as descriptive statistics.

The following test were used: Chi-Square test was used to test the association variables for categorical data. Student's t-test was used to assess the statistical significance of the difference between two population means in a study involving independent samples. P value was considered significant as the following:

* $P > 0.05$: Non-significant.

* $P \le 0.05$: Significant

RESULTS

Table (1): Comparison between supine group and alternate positions group regarding demographic data

			Supine group	Alternate group	t.test	P. value
Age (days)		Mean ± SD	1.28 ± 1.09	1.495 ± 1.32	-.775-	0.440
Birth weight (kg)		Mean ± SD	2.84 ± 0.47	2.824 ± 0.489	.146	0.884
Sex	Female	No.	19	17	X^2 0.198	0.656
		%	46.3%	41.5%		
	Male	No.	22	24		
		%	53.7%	58.5%		

There was no statistically significant difference between supine group and alternate positions group regarding age (days), birth weight (kg) and Sex (Table 1).

Table (2): Comparison between supine group and alternate positions group regarding duration of MV (days)

		Supine group (No.= 41)	Alternate group (No.= 41)	t.test	P. value
duration of MV (days)	Mean ± SD	5.22 ± 2.35	9.05 ± 19.98	-1.218-	0.227

There was no statistically significant difference between supine group and alternate positions group regarding duration of MV (days) (Table 2).

Table (3): Comparison between supine group and alternate positions group regarding FiO_2 (%) at 8 hr, 16 hr and 1 hr draw

		Supine group (No.= 41)	Alternate group (No.= 41)	t.test	P. value
FiO_2 (%) at 8 hr	Mean ± SD	48.66 ± 11.18	43.29 ± 11.92	2.102	0.039
FiO_2 (%) at 16 hr	Mean ± SD	40.37 ± 11.20	39.98 ± 8.94	.174	0.862
FiO_2 (%) at 1 hr drawl	Mean ± SD	24.29 ± 2.88	24.39 ± 2.78	-.156-	0.877

There was statistically significant increase in FiO_2 (%) at 8 hr among supine group than among alternate positions group. There was no statistically significant difference between supine group and alternate positions group regarding FiO_2 (%) at (16 hr and 1 hr draw) (Table 3).

Table (4): Comparison between supine group and alternate positions group regarding PIP (cm H_2O) at 8 hr and 16 hr

		Supine group (No.= 41)	Alternate group (No.= 41)	t.test	P. value
PIP (cm H_2O) at 8 hour	Mean ± SD	14.02 ± 1.93	15.12 ± 1.73	-2.708-	0.008
PIP(cm H_2O) at 16 hour	Mean ± SD	14.05 ± 2.29	15.10 ± 1.74	-2.333-	0.022

There was statistically significant decrease in PIP (cm H_2O) at (8 hr and 16 hr) among supine group than among alternate positions group (Table 4).

Table (5): Comparison between supine group and alternate positions group regarding PEEP (cm H_2O) at 8 hr and 16 hr

		Supine group (No.= 41)	Alternate group (No.= 41)	t.test	P. value
PEEP (cm H_2O) at 8 hour	Mean ± SD	4.76 ± 0.88	5.20 ± 0.813	-2.335-	0.022
PEEP (cm H_2O) at 16 hour	Mean ± SD	4.90 ± 0.831	5.29 ± 1.05	-1.861-	0.066

There was statistically significant decrease in PEEP (cm H_2O) at 8 hour among supine group than among alternate positions group. There was no statistically significant difference between supine group and alternate positions group regarding PEEP (cm H_2O) at 16 hour (Table 5).

Table (6): Comparison between supine group and alternate positions position group regarding RR (times/min) at 8 hr, 16 hr and 1 hr draw

		Supine group (No.= 41)	Alternate group (No.= 41)	t.test	P. value
RR (times/min) at 8 hour	Mean ± SD	43.63 ± 5.87	44.37 ± 7.22	-.503-	0.616
RR (times/min) at 16 hour	Mean ± SD	42.83 ± 3.66	43.10 ± 6.449	-.232-	0.817
RR (times/min) at 1 hour draw	Mean ± SD	41.22 ± 5.68	39 ± 4.68	1.785	0.079

There was no statistically significant difference between supine group and alternate positions group regarding RR (times/min) at 8 hr, 16 hr and 1 hr draw (Table 6).

Table (7): Comparison between supine group and alternate positions group regarding VT (ml) at 8 hr and 16 hr

		Supine group (No.= 41)	Alternate group (No.= 41)	t.test	P. value
VT(ml) at 8 hr	Mean ± SD	5.75 ± 1.13	4.89 ± 0.32	4.686	0.000
VT(ml) at 16 hr	Mean ± SD	5.77 ± 0.91	5.08 ± 0.29	4.633	0.000

There was statistically significant increase in VT (ml) at 8 hr and 16 hr among supine group than among alternate positions group (Table 7).

Table (8): Comparison between supine group and alternate positions group regarding MV (RR*VT) (ml/min) at 8 hr and 16 hr

		Supine group (No.= 41)	Alternate group (No.= 41)	t.test	P. value
MV (RR*VT) (ml/min) at 8 hr	Mean ± SD	248.55 ± 56.37	217.54 ± 41.62	2.833	0.006
MV (RR*VT) (ml/min) at 16 hr	Mean ± SD	239.04 ± 47.89	220.35 ± 35.03	2.017	0.047

There was statistically significant increase in MV (RR*VT) (ml/min) at 8 hr and 16 hr among supine group than among alternate positions group (Table 8).

Table (9): Comparison between supine group and alternate positions group regarding PaO_2 (mm Hg) at 8 hr, 16 hr and 1 hr drawl

		Supine group (No.= 41)	Alternate group (No.= 41)	t.test	P. value
PaO_2 (mm Hg) at 8 hr	**Mean ± SD**	40.36 ± 30.03	66.83 ± 45.14	-3.125-	0.002
PaO_2 (mm Hg) at 16 hr	**Mean ± SD**	71.51 ± 55.38	76.61 ± 50.64	-.435-	0.665
PaO_2 (mm Hg) at 1 hr draw	**Mean ± SD**	46.317 ± 36.05	91.91 ± 62.92	-4.026-	0.000

There was no statistically significant difference between supine group and alternate positions group regarding PaO_2 (mm Hg) at 16 hr. There was statistically significant decrease in PaO_2 (mm Hg) at 8 hr and 1 hr draw among supine group than among alternate positions group (Table 9).

Table (10): Comparison between supine group and alternate position group regarding $PaCO_2$ (mm Hg) at 8 hr, 16 hr and 1 hr draw

		Supine group (No.= 41)	Alternate group (No.= 41)	t.test	P. value
$PaCO_2$ (mm Hg) at 8 hr	**Mean ± SD**	36.02 ± 12.13	39.09 ± 11.08	-1.195-	0.236
$PaCO_2$ (mm Hg) at 16 hr	**Mean ± SD**	33.24 ± 15.05	34.77 ± 9.66	-.548-	0.585
$PaCO_2$ (mm Hg) at 1 hr draw	**Mean ± SD**	40.27 ± 10.10	41.96 ± 9.65	-.777-	0.440

There was no statistically significant difference between supine group and alternate group regarding $PaCO_2$ (mm Hg) at 8 hr, 16 hr and 1 hr draw (Table 10).

Table (11): Comparison between supine group and alternate positions group regarding OI (PaO_2/FiO_2) at 8 hr, 16 hr and 1 hr draw

		Supine group (No.= 41)	Alternate group (No.= 41)	t.test	P. value
OI (PaO_2/FiO_2) at 8 hr	**Mean ± SD**	87.21 ± 64.82	156.06 ± 103.37	-3.613-	0.001
OI (PaO_2/FiO_2) at 16 hr	**Mean ± SD**	177.42 ± 159.47	203.18 ± 125.68	-.813-	0.419
OI (PaO_2/FiO_2) at 1 hr drawl	**Mean ± SD**	195.06 ± 158.84	375.07 ± 288.69	-3.498-	0.001

There was no statistically significant difference between supine group and alternate positions group regarding OI (PaO_2/FiO_2) at 16 hr. There was statistically significant decrease in OI (PaO_2/FiO_2) at 8 hr and 1 hr draw among supine group than among alternate positions group (Table 11).

DISCUSSION

This study demonstrated that, there were no statistically significant difference between supine group and alternate group regarding sex, age (days), birth weight (kg) and duration of MV (days).

This study showed that there were statistically significant decrease in VT (ml) at 8 hr and 16 hr among alternate group than among supine group. In addition, OI and PaO_2, at 8 and 16 h in alternate position group were higher than those in supine position group were. This indicated that the oxygenation and respiratory mechanics were significantly improved in alternate position group than those in supine position group, and the improvement was enhanced over time as was reported.

Currently recognized view about ventilation in dorsal position is to improve the ratio of ventilation/blood flow (V/Q) and reduce pulmonary shunt (intrathoracic pressure gradually decreases along the direction of gravity from upside to downside, or even becomes positive pressure). In the case of respiratory failure, the positive intrathoracic pressure in most prolapse area was so large that no adequate negative pressure was produced at the end of inhalation leading to alveolar collapse in the prolapse area. Ventilation in dorsal position resulted in large sternum diaphragmatic mobility in the sternum side, most VT in the sternum side and few blood flows. Several blood flows in the dorsal side and few air flows lead to increased shunt and more unreasonable V/Q ratio [5].

Ventilation in prone position resulted in gradient decrease in the gravity distribution of intrapleural pressure, which was even from upside to downside. Transpulmonary pressure was also even so that the previously collapsed alveoli in dorsal lung could re-dilate. The ventilation throughout the lung was even, with matched V/Q and reduced shunt; as a result, the oxygenation was improved [6].

The improvement in the respiratory mechanics may be related to the thoracic stability in breath and the motion amplitude of the diaphragm. In dorsal position, the heart oppressed the lung tissue directly in the dorsal side of chest wall, while in the prone position, the heart weight oppressed the sternum, thus helped relieve the oppression of lung tissue in the dorsal side of the sternum by the heart, and improved ventilation in local lung tissue and blood perfusion [7].

Prone position can improve oxygenation and save time for the treatment. **Gattinoni *et al.*** [8] reported that the survival of severe Acute respiratory distress syndrome (ARDS) patients could be increased significantly in prone position. Recently, a controlled study report in France Croix-Rousse Hospital ICU, suggested that the ventilation in prone position for 12 h daily could significantly decrease the mortality in severe ARDS patients ($PaO_2/FiO_2<150$ mm Hg, $FiO_2 \geq 0.5$ and PEEP ≥ 5 cm H_2O for 12–24 h). This report also indicated that severe ARDS patients should receive ventilation in prone position as soon as possible. Appropriate extended duration of the ventilation in prone position could improve the prognosis [4]. These results are in agreement with our results.

This study showed that, there were statistically significant decrease in PEEP (cm H_2O) at 8 hour among supine group than among alternate group. There was no statistically significant difference between supine group and alternate group regarding PEEP (cm H_2O) at 16 hour. It is worth to mention that the interaction between PEEP and posture on regional distribution of ventilation was recently examined in anesthetized human volunteers. It was found that after the addition of PEEP in the prone position there is a much greater redistribution to ventral areas for blood flow than for ventilation, causing increased V/Q mismatch. In the study of **Petersson *et al.*** [9], without PEEP, the vertical ventilation-to-perfusion gradient was less in prone postures than in supine, but with PEEP, the gradient was similar. Although this finding supports prior studies, which have shown that lower PEEP is needed to maintain oxygenation in the prone posture than in the supine [10], reductions of PEEP are inappropriate, at least when V/Q matching and systemic oxygenation are being evaluated [11].

There was no statistically significant difference between supine group and alternate group regarding $PaCO_2$ (mm Hg) at 8 hr, 16 hr and 1 hr draw. The CO_2 clearance is becoming impaired due to structural changes of the lung [12] and the increase in dead space proves to be a prognostic marker of ARDS mortality [13]. Interestingly, turning the ARDS patient to prone position does not always result in decrease in arterial CO_2 because the presence of aerated alveoli does not necessarily mean that they are also well ventilated. In fact, it has been suggested that oxygen and carbon dioxide responses to prone position are independent and a decrease in $PaCO_2$ to the first pronation rather than an increase in PaO_2/FiO_2, is significantly associated with lung recruitability and a better outcome [14]. It has been proposed that in $PaCO_2$ nonresponders, the primary mechanism of the PaO_2 increase is diversion of the blood flow, whereas in $PaCO_2$ responders the primary mechanism is greater dorsal recruitment in comparison to ventral derecruitment, combined with reduced alveolar overinflation [15]. The $PaCO_2$ responders seem to have a higher potential to be recruited with prone positioning than with nonresponders, revealing a difference in underlying lung pathologies [16]. It has also been suggested that when PaO_2 increases and $PaCO_2$ does not simultaneously decrease, it is a sign that either cardiac output is lowered or alveolar dead space ventilation is increased by PEEP, reflecting lung overdistention [17].

This study showed that, There were statistically significant decrease in PaO_2 (mm Hg) at 8 hr and 1 hr draw among supine group than among alternate group. There was no statistically significant difference between supine group and alternate group regarding PaO_2 (mm Hg) at 16 hr. **Yao *et al.*** [18] showed that preterm infants 1 and 6 hours after weaning from mechanical ventilation had a higher PaO_2 in prone position compared to supine position. **Abdeyazdan *et al.*** [19] results showed that in prone position the mean of SPO_2 was significantly higher than in supine position. However, in this study, unlike Yao's study, assessing the tissue oxygenation was conducted using pulse oxymeter and the infants underwent mechanical ventilation at the time of intervention and at their first week of post natal. The present study was in accordance with study of **Chang *et al.*** [20] regarding the study population and method of infants' evaluation and results.

Oxygenation: It is well known that there is normally a regional difference in intrapleural pressure, being more subatmospheric at the apex and at the nondependent lung areas. This is clearly a gravity dependent phenomenon and results in exponentially regional differences in transpulmonary pressure and thus in the size of alveoli. The transpulmonary pressure, i.e. the distending forces of the lung, decreases along the ventral-to-dorsal axis and the size of the alveolar units decreases toward the dependent areas. It was found that by turning the patient to the prone position due to thoracic-lung shape modifications of the intrapleural pressure becomes less negative in non-dependent and less positive in dependent regions [(21)]. The net effect of prone positioning is not only the increase of regional inflation distribution in dorsal regions and decrease in ventral regions respectively, but intrapleural pressure, transpulmonary pressure and regional inflation distribution become more homogeneous throughout the lung [(22)]. It was early suggested that this could be explained by the reversal of lung weight gradients, the direct transmission of the weight of the heart to subjacent regions, direct transmission of the weight of abdominal contents to caudal regions of the dorsal lung and/or regional mechanical properties and shape of the chest wall and lung [(23)].

CONCLUSION

- Oxygenation and respiratory mechanics were significantly improved in prone position group than those in supine position group.
- The physiological basis of prone positioning seems to act beneficially improving hemodynamics, gas exchange and respiratory mechanics.

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