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Early High Frequency Oscillatory Ventilation in Prone Position in Pediatric Acute Respiratory Failure

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ABSTRACT

Background: High frequency oscillatory ventilation (HFOV) is a form of nonconventional ventilatory support employed for severe respiratory failure in children.

Aim of the study: Was to compare the impact of early high frequency oscillatory ventilation (within 24 hours of endotracheal intubation) versus pressure controlled mechanical ventilation (P-CMV) and /or late high frequency oscillatory ventilation in patient with acute respiratory failure in prone position. **Patients and Methods:** Thirty-nine pediatric patients (19 males and 20 females) aged (2 to 156 months) were admitted in pediatric intensive care unit (PICU), Tanta University Hospital. They were categorized into 3 groups: *Group I*; 15 patients were monitored on early HFOV (within 24 hours from intubation). *Group II*; 18 patients were monitored on P-CMV. *Group III*; **6** patients were monitored on late HFOV (24 hours after intubation). All patients were subjected to scoring systems for Pediatric Risk for Mortality (PRISM III) and Sequential Organ Failure Assessment (SOFA) they were also monitored for [pulse oximetry, blood pressure, oxygenation Index, oxygenation saturation index, lung mechanics (compliance and resistance), ventilation parameters **(**HFOV and P-CMV) and Trans-Esophageal Doppler. **Results:** PP had superiority over SP in improvement of oxygenation / ventilation parameters demonstrated by the increased (PaO2, SaO2,pH) /decreased PaCO2, OI, OSI, FiO2 without harmful affection on HD. PP improve lung mechanics demonstrated by increased lung compliance with decreased airway resistance. PP can be safely applied in pediatrics. **Conclusion**: Early HFOV had superiority over CMV/late HFOV showed by the improvement in Oxygenation/ventilation**.**

Keywords: High Frequency Oscillatory Ventilation, Prone Position, Pediatric, Acute Respiratory Failure.

INTRODUCTION

The use of protective ventilatory strategies that prevent further lung injury associated with MV is a major concern. HFOV and PP are protective ventilatory strategy, as they optimize alveolar recruitment and lung volume, as well as improve oxygenation. HFOV appears to represent an important therapeutic option in ventilatory support of children with respiratory failure [(1)].

HFOV results in a tidal volume that is smaller than the anatomic dead space and is considered an advanced mode of ventilation [(2)].

AIM OF THE STUDY

It was to compare the impact of early high frequency oscillatory ventilation (within 24 hours of endotracheal intubation) versus pressure controlled mechanical ventilation (P-CMV) and /or late high frequency oscillatory ventilation in patient with acute respiratory failure in prone position.

PATIENTS AND METHODS

This prospective study was carried out during the period from June 2017 to October 2018 upon 39 pediatric patients (19 males and 20 females) aged from 2 to 156 months and were admitted in PICU, Tanta University Hospital. They were divided in to 3 groups: **Group I**: 15 patients were monitored on early HFOV (within 24 hours from intubation). **Group II**: 18 patients were monitored on P-CMV. **Group III:** 6 patients were monitored on late HFOV (24 hours after intubation).

Inclusion criteria: All mechanically ventilated patients with ARF admitted to PICU of Tanta University Hospital on either: HFOV or P-CMV

Exclusion criteria: Patient expected to be extubated within 24 hours or contraindicated for prone position or cases with inability to introduce cardioQ probe like esophageal stricture.

Written informed consent was obtained from the parents or guardians of each child. The study was approved by the Ethics Committee of Faculty of Medicine, Tanta University.

Collection of data: All the studied patients were subjected to the following**:**

1. **Detailed history taking with special emphasis on:**
   - Demographic data: name, age, sex and socio-

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economic status.
- Cause of PICU admission.
- Initial symptoms: date of onset of symptoms, its duration and course of illness.
- Cardiac symptoms as dyspnea, cyanosis, edema and palpitation.
- Pulmonary symptoms as: wheezes, respiratory distress and cough.

2. Thorough clinical examination including vital signs with special emphasis on:
- Anthropometric measurements: weight, height and vital data.
- Cardiac and respiratory systems, e.g.: heart sounds, murmurs, breathe sounds and additional sounds.

3. Routine Laboratory Investigations:
- Complete Blood Count (CBC).
- C- reactive protein (CRP).
- Arterial blood gases (ABGs) sample taking from arterial blood [*blood gas analyzer Stat Profile ® pHOx ® Series plus nova biomedical UK*: *Innovation house Aston lane South, Runcan, Cheshire WA7, 3FY, UK*].

4. Scoring systems for patients:
- **Pediatric Risk for Mortality (PRISM) III scoring** was obtained from each patient immediately on admission [(3)].
- **Sequential Organ Failure Assessment (SOFA)** scoring was obtained from each patient 48 hours after admission [(4)].

5. Monitoring: All patients were turned to the PP for half an hour. Before and at the end of PP time, the patients were monitored for the selected measurements that were repeated twice in consecutive two days. They were monitored for:
- **Noninvasive investigation**:
  - Pulse oximetry (*Bedside monitor, BSM-4113K, Nihon Kohden Corp., Tokyo, Japan*) over full-perfused area (*mostly over digits of upper limbs*) to continuously monitor SaO2.
  - Blood pressure (*Bedside monitor, BSM-4113K, Nihon Kohden Corp., Tokyo, Japan*).
- **Oxygenation Index:** ($F_iO2 \times MAP / PaO2) \times 100$ [(5)].
  - OI<4 (at risk), OI 4-7.9 (*mild hypoxemia*), OI 8-15.9 (*moderate hypoxemia*), ≥5 -10 (*20%mortality rate*), ≥10 (*50% mortality rate*), OI >16 (*severe hypoxemia*), ≥ 40 (*need for ECMO*). MAP: Mean airway pressure.
- **Oxygenation Saturation Index: (FiO2 × MAP/SaO2) × 100**
- **Lung mechanics[(6)]:**
  - A- Compliance; C = ΔV /ΔP
  - B- Resistance; Raw=P plat /peak inspiratory flow rate.
- **Ventilation parameters e.g.:**

  1- HFOV: MAP, ΔP, Frequency and FiO2 Device: Ventilation was accomplished using a [*Fabian HFOV" "ACUTRONIC" Medical Systems AG Fabrik im Schiffli 8816 Hirzel / Switzerland*].

  2-P-CMV: FiO2, TI, PIP, RR and PEEP. Ventilation was accomplished using a Raphael color ventilator, [*Model X1, Hamillton medical, Hamilton Medical AG, CH- 7403Rhazuns, Switzerland*]
- **Trans-Esophageal Doppler [(7)].**
- Monitoring of: [Stroke volume - Stroke volume index - Cardiac output - Cardiac index - Systemic vascular resistance -Systemic vascular resistance index]
- **Principal of assay [(7)]:**
- CardioQ-ODM manufactured by Deltex Medical of Chichester UK was used **[***Cardio Q ODM, Model No 9051-6935, DELTEX MEDICAL LTD PO19 8 TX UK, 2008***].**
- Pediatric Doppler probes were used: (*KDP72*) Doppler Probe (*Product Code: 9081-7001) 72-hour pediatric oral Doppler probe.*

Ethical approval:

The study was approved by the Ethics Board of Tanta University and an informed written consent was taken from each participant in the study.

Statistical analysis

Statistical analysis was done using IBM SPSS version 23. Data were expressed as mean ± SD, range, median, frequency and percentage and were analyzed using the following tests:[*independent student "t" test - chi-square (χ^2) test - ANOVA with repeated measures - Fisher's Exact or Monte Carlo correction - McNemar-Bowker - Mann Whitney test'6 and Wilcoxon signed ranks test*] to assess the significance of difference in the levels between different parameters. $P < 0.05$ was accepted as significant. *Spearman coefficient* to correlate between two abnormally quantitative variables

RESULTS

Laboratory assessments of the measured parameters are presented in the following tables and figures:

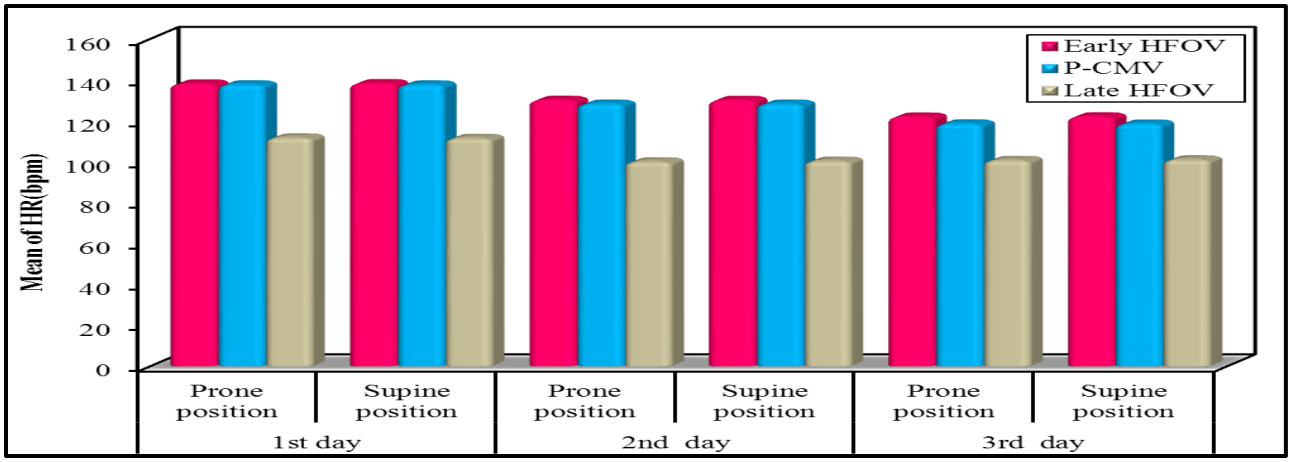

Figure (1): Comparison of heart rate (bpm) between the studied groups.

- **Figure (1)** showed heart Rate (bpm) distribution between the studied groups.

○ Regarding early HFOV:

- There was statistically significant increase in 1st and 2nd compared to 3rd day in PP.
- There was statistically significant increase in 1st and 2nd compared to 3rd day in SP.

○ Regarding P-CMV:

- There was statistically significant increase in 1st and 2nd compared to 3rd day in PP.
- There was statistically significant increase in 1st and 2nd compared to 3rd day in SP.

○ Comparison in between PP groups:

- There was statistically significant increase in early HFOV and P-CMV compared to late HFOV in 1st and 2nd days.
- Otherwise, there was no statistically significant difference between studied groups.

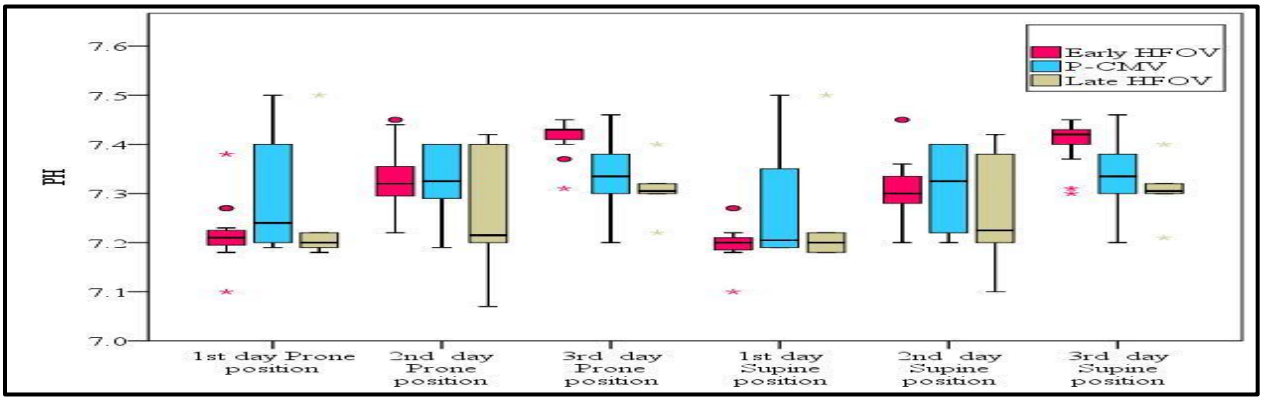

Figure (2): Comparison of pH between the studied groups.

- **Figure (2)** showed pH distribution in the studied groups.

○ Regarding early HFOV:

- There was statistically significant decrease in 1st compared to 2nd day in PP.
- There was statistically significant decrease in 1st and 2nd compared to 3rd day in PP. There was statistically significant decrease in 1st compared to 2nd day in SP.
- There was statistically significant decrease in 1st and 2nd compared to 3rd day in SP.
- There was statistically significant decrease in SP compared to PP in 2nd day.

○ Regarding P-CMV:

- There was statistically significant decrease in 1st compared to 2nd and 3rd days in SP.
- There was statistically significant decrease in SP compared to PP in 1st day.

○ Comparison in-between PP groups:

- There was statistically significant decrease in the P-CMV and late HFOV compared to early HFOV in 3rd day.
- Otherwise, there was no statistically significant difference between studied groups.

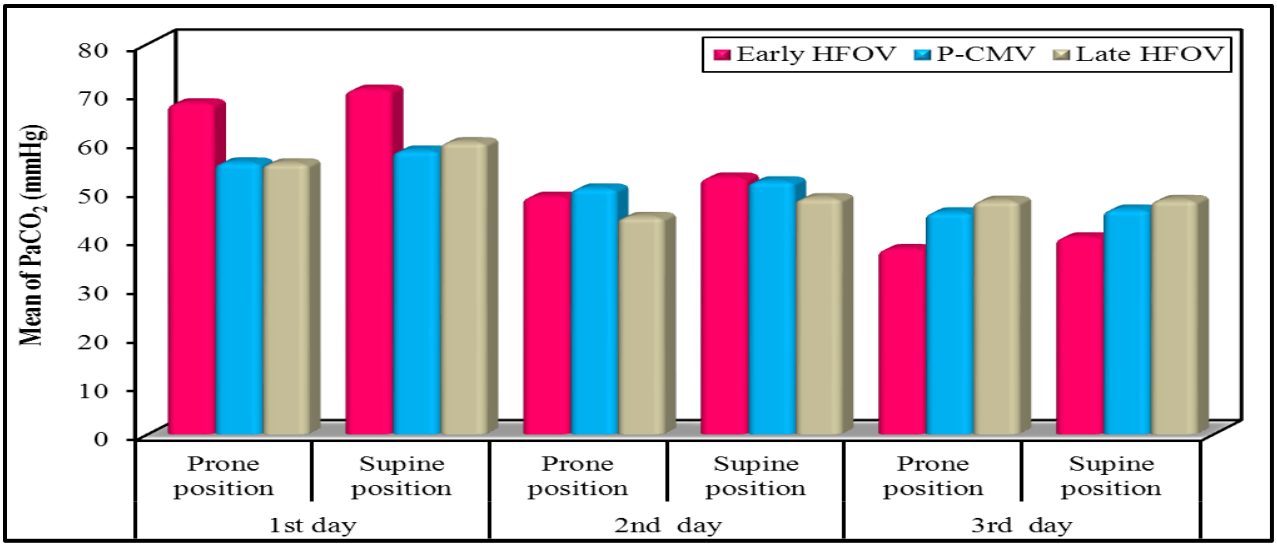

Figure (3): Comparison of partial pressure of arterial carbon dioxide (mmHg) between the different groups.

- **Figure (3)** showed partial pressure of arterial carbon dioxide (mmHg) distribution in the studied groups.

○ Regarding early HFOV:

- There was statistically significant increase in SP compared to PP in 1st and 2nd days.
- There was statistically significant increase in 1st compared to 2nd day in PP.
- There was statistically significant increase in 1st and 2nd compared to 3rd day in PP.
- There was statistically significant increase in 1st compared to 2nd day in SP.
- There was statistically significant increase in 1st and 2nd compared to 3rd day in SP.

○ Regarding P-CMV:

- There was statistically significant increase in SP compared to PP in 1st and 2nd days.
- There was statistically significant increase in 1st compared to 3rd day in PP.
- There was statistically significant increase in 1st compared to 3rd day in SP.

○ Comparison in-between PP groups**:**

- There was statistically significant increase in P-CMV and late HFOV compared to early HFOV in 3rd day.
- Otherwise, there was no statistically significant difference between studied groups.

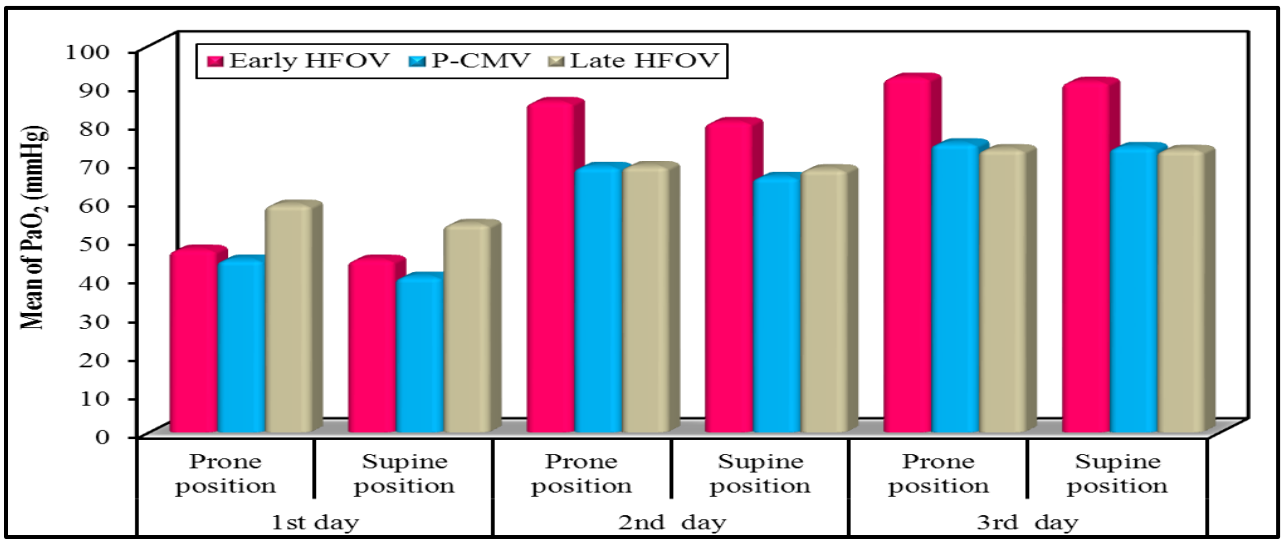

Figure (4): Comparison of partial pressure of arterial oxygen (mmHg) between the studied groups.

- **Figure (4)** showed partial pressure of arterial oxygen (mmHg) distribution in the studied groups.

○ Regarding early HFOV:

- There was statistically significant decrease in SP compared to PP in 1st and 2nd days.
- There was statistically significant decrease in 1st compared to 2nd day in PP.
- There was statistically significant decrease in 1st and 2nd compared to 3rd day in PP.
- There was statistically significant decrease in 1st compared to 2nd day in SP.

-There was statistically significant decrease in 1st and 2nd compared to 3rd day in SP.

○ Regarding P-CMV:

-There was statistically significant decrease in SP compared to PP during studied periods.
-There was statistically significant decrease in 1st compared to 2nd day in PP.
-There was statistically significant decrease in 1st and 2nd compared to 3rd day in PP.
-There was statistically significant decrease in 1st compared to 2nd day in SP.
-There was statistically significant decrease in 1st and 2nd compared to 3rd day in SP.

○ Regarding late HFOV:

-There was statistically significant decrease in SP compared to PP in 1st day.
-There was statistically significant decrease in 1st compared to 3rd day in PP.
-There was statistically significant decrease in 1st compared to 3rd day in SP.

○ Comparison in-between PP groups:

-There was statistically significant decrease in early HFOV and P-CMV compared to late HFOV in 1st day.
-There was statistically significant decrease in P-CMV and late HFOV compared to early HFOV in 2nd and 3rd days.

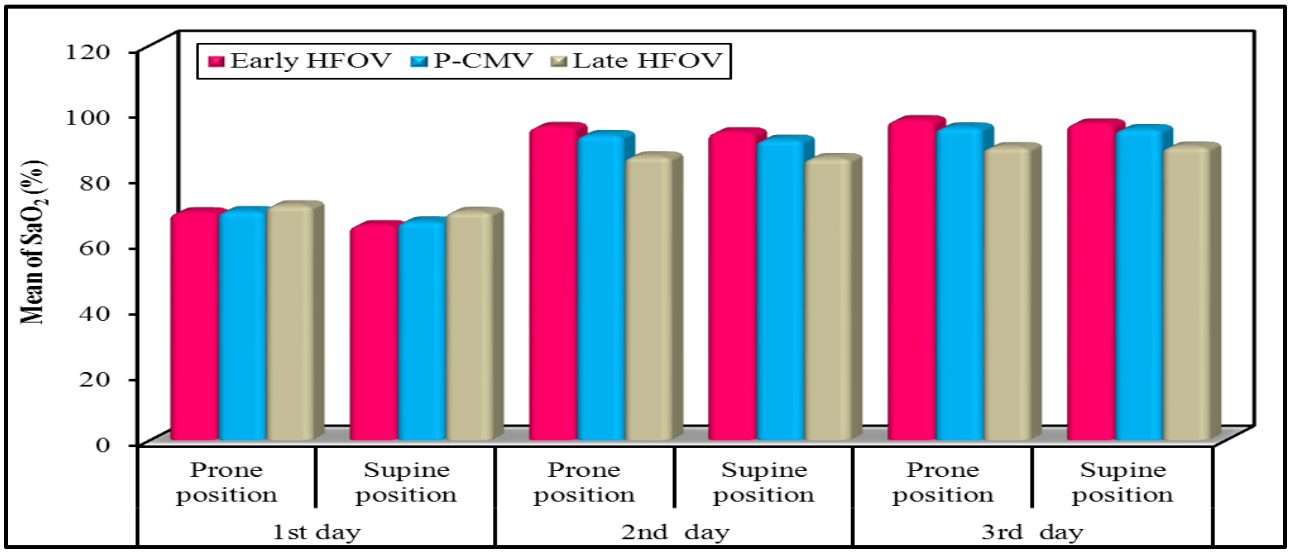

Figure (5): Comparison of oxygen saturation (%) between the studied groups

▪ **Figure (5)** showed oxygen saturation (%) distribution in the studied groups.

○ Regarding early HFOV:

-There was statistically significant decrease in SP compared to PP in 1st and 2nd days.
-There was statistically significant decrease in 1st compared to 2nd and 3rd days in PP.
-There was statistically significant decrease in 1st compared to 2nd and 3rd days in SP.
-There was statistically significant decrease in 2nd compared to 3rd day in SP.

○ Regarding P-CMV:

-There was statistically significant decrease in SP compared to PP during studied periods.
-There was statistically significant decrease in 1st compared to 2nd and 3rd days in PP.
-There was statistically significant decrease in 1st compared to 2nd and 3rd days in SP.
-There was statistically significant decrease in 2nd compared to 3rd day in SP.

○ Regarding late HFOV:

-There was statistically significant decrease in SP compared to PP in 1st day.
-There was statistically significant decrease in 1st compared to 3rd day in PP.
-There was statistically significant decrease in 1st compared to 3rd day in SP.

○ Comparison in-between PP groups:

-There was statistically significant decrease in late HFOV compared to early HFOV in 2nd and 3rd days.
-There was statistically significant decrease in late HFOV compared to P-CMV in 3rd day.
-Otherwise, there was no statistically significant difference between studied groups.

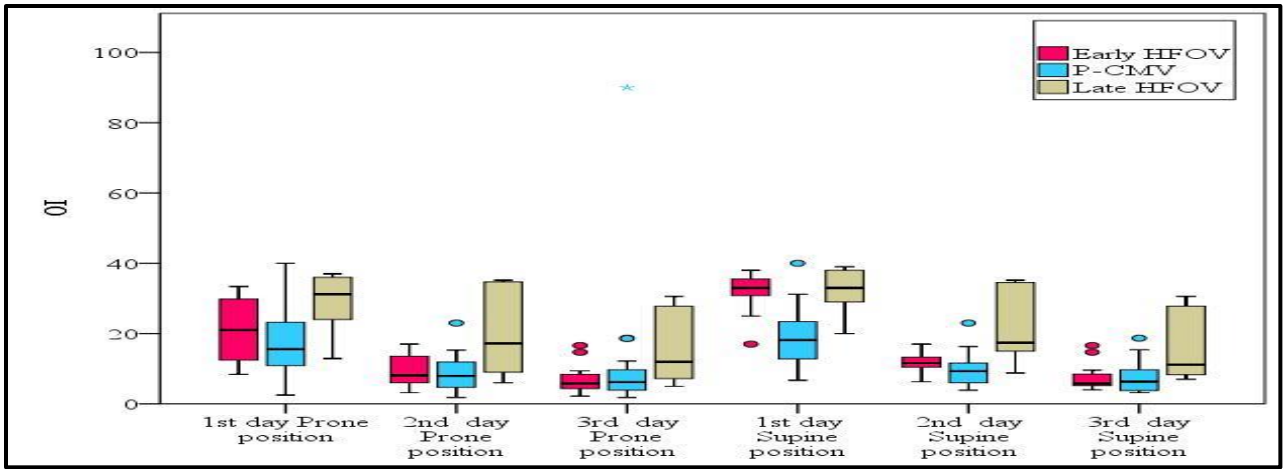

Figure (6): Comparison of oxygen saturation index between the studied groups.

- **Figure (6)** showed oxygen saturation index distribution in the studied groups.

○ Regarding early HFOV:
- There was statistically significant increase in SP compared to PP during studied periods.
- There was statistically significant increase in 1st and 2nd compared to 3rd day in PP.
- There was statistically significant increase in 1st and 2nd compared to 3rd day in SP.
- There was statistically significant increase in 1st compared to 2nd day in SP.

○ Regarding P-CMV:
- There was statistically significant increase in SP compared to PP in 1st and 2nd days.
- There was statistically significant increase in the 1st compared to 2nd and 3rd days in PP.
- There was statistically significant increase in the 1st compared to 2nd and 3rd days in SP.
- There was statistically significant increase in the 2nd compared to 3rd day in SP**.**

○ Regarding late HFOV:
- There was statistically significant increase in SP compared to PP in1st day.
- There was statistically significant increase in 1st compared to 3rd day in PP.
- There was statistically significant increase in 1st compared to 3rd day in SP.

○ Comparison in-between PP groups:
- There was statistically significant increase in late HFOV compared to P-CMV in 1st day.
- Otherwise, there was no statistically significant difference between groups.

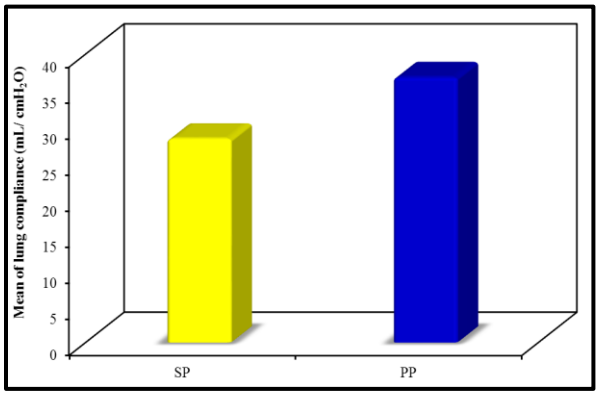

Figure (7): Comparison of Lung Mechanics [Compliance (mL/ cmH2O) between the Prone Position and Supine Position in Pressure controlled Mechanical Ventilation.

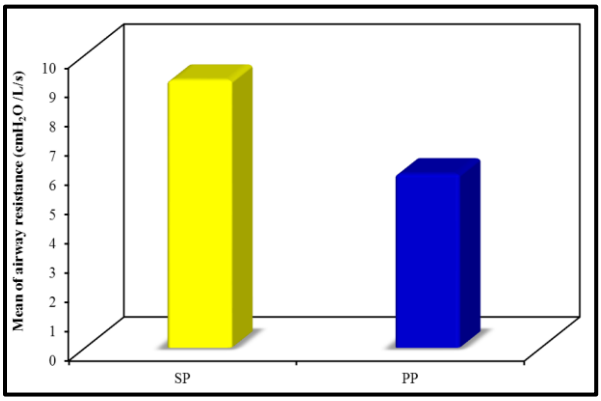

Figure (8): Comparison of Airway Resistance (cmH2O /L/s)] Between the Prone Position and Supine Position in Pressure controlled Mechanical Ventilation.

- **Figure (7, 8)** showed lung mechanics distribution in the studied groups.

○ Regarding lung compliance: There was statistically significant decrease in SP compared to PP**.**

○ Regarding airways resistance: There was statistically significant increase in SP compared to PP.

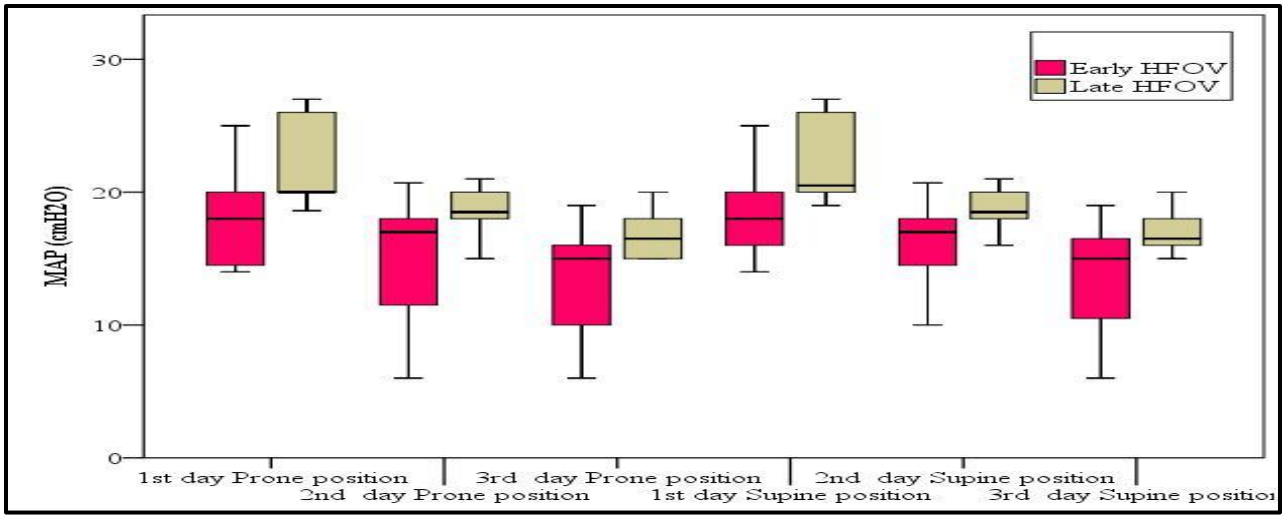

Figure (9): Comparison of mean airway pressure (cmH2O) between prone and supine positions.

- **Figure (9)** showed mean airway pressure (cmH2O) between prone position and supine Position.

○ Regarding early HFOV:
- There was statistically significant increase in SP compared to PP in 1st and 2nd days.
- There was statistically significant increase in 1st compared to 3rd day in PP.
- There was statistically significant increase in 1st and 2nd compared to 3rd day in SP.

○ Regarding late HFOV:
- There was statistically significant increase in 1st day compared to 3rd day in PP.
- There was statistically significant increase in 1st day compared to 3rd day in SP.

○ Comparison in-between PP groups:
- There was statistically significant increase in late HFOV compared to early HFOV in 1st day.
- Otherwise, there was no statistically significant difference between studied groups.

Table (1): Comparison of peak inspiratory pressure (cmH_2O) between the prone position and supine position in pressure controlled mechanical ventilation

PIP (cmH_2O)		1st day	2nd day	3rd day	F_1	p_1
P-CMV	**Prone position**	18.11 ± 5.20	17.67 ± 4.38	17.33 ± 4.34	0.814	0.452
	Supine position	19.17 ± 5.65	17.94 ± 4.30	17.33# ± 4.38	3.637*	0.037*
	t	**3.557**	**1.426**	**0.0**		
	p	**0.002***	**0.172**	**1.000**		

Cm H2o: centimeters Water, P-CMV: Pressure controlled Mechanical Ventilation, PIP: Peak Inspiratory Pressure
t: Paired t-test F_1: F test (ANOVA) with repeated measures, Sig. bet. periods were done using Post Hoc Test (adjusted Bonferroni) p: p value for comparing between prone position and supine position
p_1: p value for comparing between the three groups periods # significant with1st day @ significant with 2nd day

- **Table (1)** showed peak inspiratory pressure (cmH_2O) between the prone position and supine position in pressure controlled mechanical ventilation
  - There was statistically significant increase in SP compared to PP in 1st day.
  - There was statistically significant increase in 1st compared to 3rd day in SP.
  - Otherwise, there was no statistically significant difference between studied groups**.**

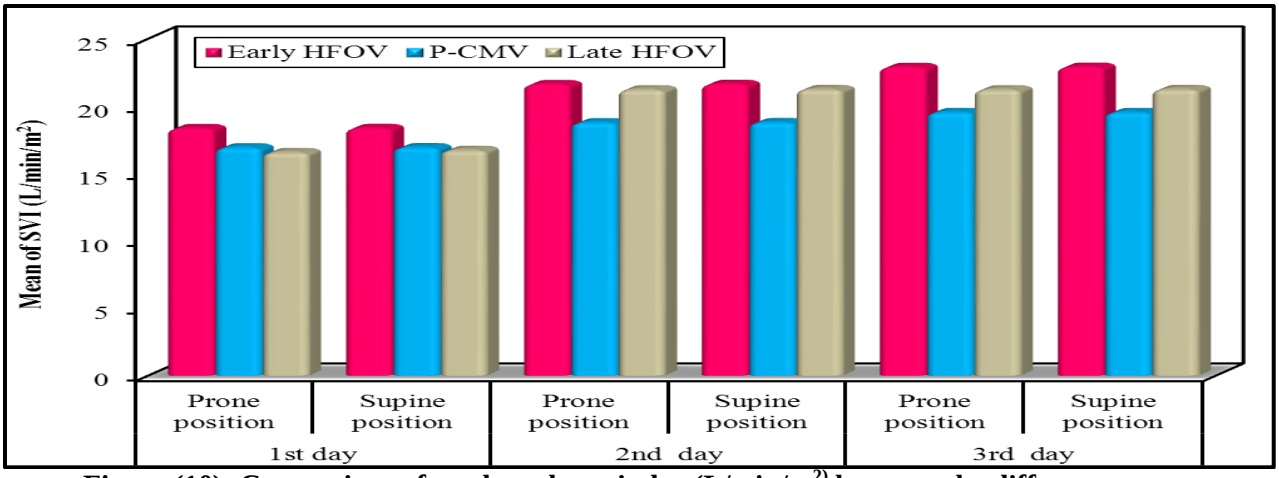

Figure (10): Comparison of stroke volume index (L/min/m$^{2)}$ between the different groups

- **Figure (10)** showed the stroke volume index (L/min/m$^{2)}$ in the studied groups
  - **Regarding P-CMV:**
    - There was statistically significant decrease in 1st compared to 2nd a`nd 3rd days in PP.
    - There was statistically significant decrease in 1st compared to 2nd and 3rd days in SP.
    - Otherwise, there was no statistically significant difference between studied groups.

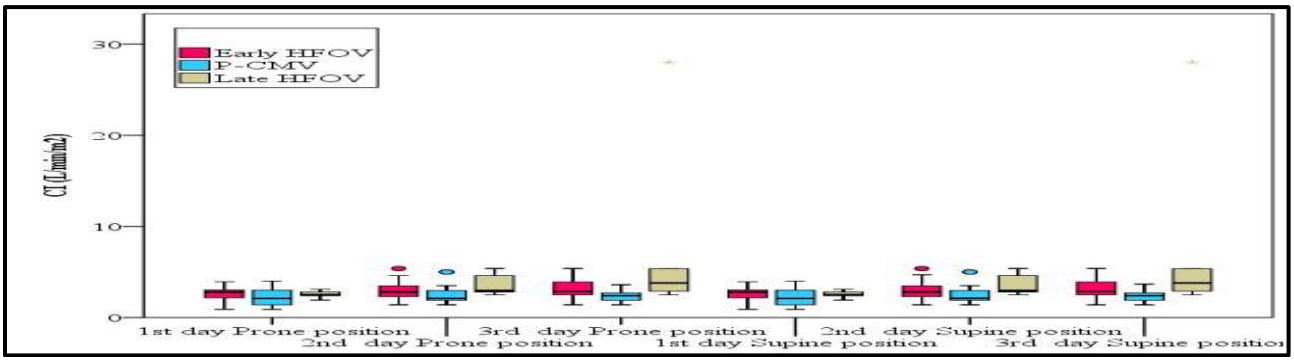

Figure (11): Comparison of cardiac output (L/min) between the studied groups

- **Figure (11)** showed the cardiac output (L/min) in the studied groups
  - Regarding early HFOV:
    - There was statistically significant decrease in 1st compared to 2nd and 3rd days in PP.
    - There was statistically significant decrease in 1st compared to 2nd and 3rd days in SP.
  - Regarding late HFOV:
    - There was statistically significant decrease in 1st compared to 2nd and 3rd days in PP.
    - There was statistically significant decrease in 1st compared to 2nd and 3rd days in SP.
  - Comparison in-between PP groups**:**
    - There was statistically significant decrease in P-CMV compared to early HFOV and late HFOV in 3rd day.
    - Otherwise, there was no statistically significant difference between studied groups.

DISCUSSION

HFOV appears to represent an important therapeutic option in ventilatory support of children with respiratory failure [(1)].

The present study showed that regarding HR, there was no difference between PP and SP. There was increase in 1st and 2nd compared to 3rd day in early HFOV and P-CMV in PP and SP. Also, there was increase in early HFOV and PCMV compared to late HFOV in 1st and 2nd days in PP. i.e. HR improved as time pass. The current study also showed that regarding pH, there was decrease in 2nd day in SP compared to PP in early HFOV. Also, there was decrease in 1st day in SP compared to PP in P-CMV. There was decrease in pH in P-CMV and late HFOV compared to early HFOV in 3rd day in PP. Regarding early HFOV, there was decrease in 1st compared to 2nd day. Also, there was decrease in 1st and 2nd compared to 3rd day in PP and SP. Regarding P-CMV

in SP, there was decrease in 1st compared to 2nd and 3rd days; i.e. pH improved as time pass. This was in accordance with **Ruste *et al.*** [8] who found that there was improvement of pH at the end of PP session. This may be explained by improvement of ventilation leading to decrease of PaCO2.

The present work showed that regarding Pa CO2, there was increase in PCMV and early HFOV in 1st and 2nd days in SP compared to PP. There was increase in P-CMV and late HFOV compared to early HFOV in 3rd day in PP. Regarding early HFOV in PP and SP, there was increase in 1st compared to 2nd day. Also, there was increase in 1st and 2nd compared to 3rd day. Regarding P-CMV in PP and SP, there was increase in 1st compared to 3rd day. i.e. PaCO2 level improved as time pass. This was in accordance with, **Yadav *et al.*** [9] who conducted a study on the effect of position on PaCO2 and PETCO2 during cervical spine surgery in prone position in adults where patients received volume-controlled ventilation. They found that there was decrease of PaCO2 with change of position from SP to PP. Likewise, ***Gouna et al.*** [10] who conducted a study to compare breathing patterns and lung function in the supine, lateral and PP in oxygen dependent preterm infants on NCPAP. They found that there was decrease transcutaneous CO2 in premature neonate after PP. They explained it by the ability of PP to improve pulmonary function by optimizing ventilatory strategy and lung volume.

The present study showed that regarding PaO2, there was decrease in early HFOV in 1st and 2nd days in SP compared to PP. Also, there was decrease in PCMV in studied periods in SP compared to PP. In addition, there was decrease in 1st day in late HFOV in SP compared to PP. Regarding PP, there was decrease in early HFOV and P-CMV compared to late HFOV in 1st day, but there was decrease in P-CMV and late HFOV compared to early HFOV in 2nd and 3rd days. Regarding early HFOV and P-CMV, there was decrease in 1st compared to 2nd day. Also, 1st and 2nd compared to 3rd day in PP and SP. regarding late HFOV, there was decrease in 1st compared to 3rd day in PP and SP. i.e. PaO2 increased as time pass. This was in accordance with **Scaravilli *et al.*** [11] who found that there was improvement of oxygenation in form of increase of PaO2 and PaO2/F**i**O**2** ratio in PP than before PP. They explained it by reducing lung ventilation perfusion mismatching and promotion of non-aerated dorsal lung area recruitment by PP. Likewise, **Papazian *et al.*** [12] found that there was improvement of oxygenation in the form of increase in PaO2/FiO2 ratio in HFOV and P-CMV groups in PP, but the increase was more in HFOV group. Correspondingly; **Demory *et al.*** [13] conducted a study to show the effect of HFOV following PP on oxygenation in adults. Patients received conventional lung protective MV in the PP. They found that there was PaO2/FiO2 ratio was higher in the CV prone – HFOV supine group than in the CV prone - CV supine. They explained it by ability of HFOV to maintain lung recruitment related to PP and thus improvement of ventilation perfusion matching.

The present work showed that regarding SOFA score, there was no difference between studied groups. This may be explained by the short time of PP (30 minutes) to allow SOFA score changes. This was in accordance with **Taccone *et al.*** [14] who conducted a study to assess possible outcome benefits of prone positioning in patients with moderate and severe hypoxemia who are affected by ARDS. They found that there was no difference of SOFA in PP than SP.

The present work showed that regarding OSI, there was increase in early HFOV in studied periods in SP compared to PP. Also, there was increase in PCMV in 1st and 2nd days in SP compared to PP. In addition, there was increase in 1st day in late HFOV in SP compared to PP. Regarding PP; there was increase in late HFOV compared to early HFOV and P-CMV in 1st and 2nd days. Also, there was increase in late HFOV compared to P-CMV in 3rd day. Regarding early HFOV, there was increase in 1st and 2nd compared to 3rd day in PP and SP. Also, there was increase in 1st compared to 2nd day in SP. Regarding P-CMV; there was increase in 1st compared to 2nd and 3rd days in PP and SP. In addition, there was increase in 2nd compared to 3rd day in SP. Regarding late HFOV, there was increase in 1st compared to 3rd day in PP and SP. i.e. OSI improved as time pass. This was in accordance with **Papazian *et al.*** [12] who found that there was decrease in OI after prone P-CMV and prone HFOV. Also, **El-Mohamady *et al.*** [15] conducted a study to show effect of inhaled nitric oxide and PP on oxygenation in children with ARDS receiving P-CMV. They found that there was decrease in OI in children after PP. **Romero *et al.*** [16] who conducted a study to evaluate the safety of extended PP ventilation and its impact on respiratory function in adult patients with severe ARDS. They applied prompt PP to patients entered the study with an OI of 22 ± 5, were remained an average of 55 straight hours on PP ventilation and were returned to supine position with an OI of 8 ± 2. This can be explained by improved oxygenation with decreased FiO2 needs and mean airway pressure. Additionally, **Muniraman *et al.*** [17] who conducted a study to evaluate the correlation of OI with OSI and validate predictive OI from noninvasive OSI measurements for clinically relevant OI values in neonate with RF. They found that strong correlation of

OI with OSI was found. Derived OI from OSI was in good agreement and strongly predictive of clinically relevant OI cutoffs from 5 to 25. Oxygenation index derived from noninvasive sources may be useful to reliably assess severity of RF and response to therapy on a continuous basis.

The present work showed that regarding lung compliance, there was decrease in SP compared to PP. This was in accordance to ***Romero et al.*** [16] who found that there was increase of lung compliance after PP. They explained that by rise in static compliance probably reflect recruitment of alveolar units and dead space reduction.

The current study showed that regarding airway resistance, there was decrease in PP compared to SP. This was in accordance to **Vieillard-Baron *et al.*** [18] who conducted study to test the hypothesis that ventilation in PP might improve homogenization of VT in ARDS patients on controlled MV. They found decrease of lung resistance in PP than SP. This may be explained by hominization of V/Q matching with inflation of alveoli which lead to direct traction on airways increasing the caliber.

The present study showed that MAP, there was increase in SP compared to PP in 1st and 2nd days in early HFOV. Regarding PP, there was increase in 1st day in late HFOV compared to early HFOV. Regarding early HFOV, there was increase in 1st day compared to 3rd day in PP and SP. Also, there was increase in 2nd compared to 3rd day in SP. Regarding late HFOV, there was increase in 1st day compared to 3rd day in PP and SP. i.e. MAP improved as time pass. This was in accordance to **curley *et al.*** [19] who conducted study to show effect of PP on clinical outcomes in children with ALI. The prone group was initially supported on HFOV. They found that there was decrease of MAP. This may be explained by improvement of the studied cases.

The present work showed that regarding ΔP, there was increase in SP compared to PP in 1st day in early HFOV. Regarding PP, there was increase in 1st day in late HFOV than compared to early HFOV. Regarding early HFOV, there was increase in the 1st compared to 3rd day in PP and SP. As regard late HFOV, there was increase in the 1st compared to 3rd day in SP. i.e. ΔP improved as time pass. This was in contrast with **Papazian *et al.*** [12] who found that there was no change in ΔP. This may be explained by improvement of the studied cases.

The present work showed that regarding F**i**O**2**, there was increase in SP compared to PP during studied periods in early HFOV. Regarding PP, there was increase in early HFOV and late HFOV compared to P-CMV in 1st day. As regard early HFOV, there was increase in 1st and 2nd compared to 3rd day in PP and SP. Also, there was increase in 1st compared to 2nd day in SP. Regarding P-CMV; there was increase in 1st compared to 3rd day in PP. There was increase in 1st and 2nd compared to 3rd day in SP. Regarding late HFOV, there was increase in 1st compared to 3rd day in PP and SP. i.e. FiO2 decreased as time pass. This was in accordance with **Guerin *et al.*** [20] who conducted study to show the effect of early application of prolonged PP in adult patients with ARDS receiving volume controlled MV. They found that there was decrease of FiO2 in PP. This may be explained by improvement of pulmonary function with improvement of oxygenation.

The present work showed that regarding PIP, there increase in SP compared to PP in 1st day. There was increase in 1st compared to 3rd day in SP. i.e. PIP decrease as time pass. This may be explained by improvement of the studied cases. This was in accordance with **Aguirre-Bermeo *et al.*** [21] who conducted a study analyzing the variation in lung volumes and PEEP-induced lung volume recruitment with the change from SP to PP in ARDS adult patients. They found no changes in PIP.

The present work showed that regarding SVI, there was no difference in PP compared to SP. However, there was decrease in P-CMV in 1st compared to 2nd and 3rd days in PP and SP. i.e. SVI improved as time pass. This was in contrast With **Daihua *et al.*** [22] who conducted a study to investigate the effect of body position changes on stroke variation (SVV) in volume controlled ventilated adult patients with sepsis. They found that there was decrease of SVI in PP. They explained it that PP placed the heart on a hydrostatic level above the head and limbs with mild abdominal compression, which decrease vena cava return. The difference with our study may be explained by the use of pressure-controlled (pediatric) versus volume controlled (adult) ventilation

The present study showed that regarding CO, there was no difference in PP compared to SP. There was decrease in 1st day compared to 2nd and 3rd days in late HFOV group in PP and SP. i.e. CO improved as time pass. This was in accordance with **Lucchini *et al.*** [23] who found that there was no change in CO after application of PP in adult hypoxemic patients supported by Veno-venous ECMO. This was in contrast with **MA *et al.*** [24] who found that there was decrease of CO after PP in neonates. They explained that by decrease of SV without changes of HR.

In conclusion; PP had superiority over SP in improvement of oxygenation/ventilation parameters demonstrated by the increased (PaO2, SaO2, pH) /decreased PaCO2, OI, OSI, FiO2 without harmful

affection on HD. Early HFOV had superiority over P-CMV/late HFOV showed by the improvement in oxygenation/ventilation.

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