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Comparison of Volume Guarantee Ventilation and Pressure Limited Ventilation on Required Duration of Ventilation in Preterm LBW Infants

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Abstract
Background*: Volume guaranteed (VG) is a novel mode, best described as a dual loop synchronized modality that ventilates with time cycled pressure limited ventilation. It provides automatic adjustment of the peak inspiratory pressure for ensuring a minimum set tidal volume. There are limited data about the effects of VG ventilation on required duration of ventilation and short term neonatal outcomes in preterm infants with respiratory distress syndrome (RDS).*
Objective*: The objective of this study was to evaluate the effect of VG ventilation on required duration of ventilation.*
Methods*: This prospective randomized comparative study was conducted at level III b NICU of Deenanath Mangeshkar Hospital & Research Center, Pune between May2016 to April 2017. Forty six preterm infants who required mechanical ventilation were randomly divided into 2 groups [SIPPV group (n=23) and SIPPV + VG group (n=23)]. Required duration of mechanical ventilation was recorded. Post extubation CPAP duration and duration of oxygen requirement were also recorded.*
Results*: There were no significant differences between two groups in terms of demographic features. Infants ventilated with VG mode had shorter duration of ventilation (statistically not significant). Extubation failure was observed less frequently with SIPPV + VG mode of ventilation. Post extubation duration of CPAP requirement and duration of oxygen requirement were significantly less (p-value <0.05) in infants ventilated with VG mode.*
Conclusion*: In conclusion, in our study VG ventilation significantly reduced duration of CPAP and oxygen requirement in preterm infants. A trend in reduction in required duration of ventilation was also observed with VG mode of ventilation. This data favours the use of VG ventilation in respiratory support of premature infants.*
Key words: *SIPPV-Synchronized Intermittent Positive Pressure Ventillation, VG- Volume Guarantee*

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I. Introduction

Mechanical ventilation (MV) is an important tool in the care of critically sick and preterm infants as very low birth weight (VLBW) infants may require MV therapy during their hospitalization (1,2). Synchronized mechanical ventilation is used now a days. The principal advantages of synchronized mechanical ventilation such as decreased work of breathing, more comfort to patient, less need of sedation, earlier weaning process have been well documented (3). There is wide acceptance of synchronized mechanical ventilation in NICU.

The two most widely used modalities of synchronized mechanical ventilation are Synchronized Intermittent Mandatory Ventilation (SIMV) and Assist/control (AC)/ synchronized intermittent positive pressure ventilation (SIPPV).SIPPV is a Time Cycled Pressure Limited mode in which every spontaneous breath is supported by the preset peak inspiratory pressure (PIP) and the ventilation rate is triggered by the patient's respiratory rate. SIPPV typically uses a minimal mandatory back up breaths to support the infant during periodic breathing or apnea (4). During IPPV, the tidal volume delivered to the patient is dependent on lung compliance and resistance, the patient's inspiratory effort, as well as the applied ventilator pressure.

Improving lung mechanics, either because of surfactant administration or during recovery phase of respiratory distress syndrome (RDS), can lead to delivery of inadvertently large tidal volume(5). Large variations in tidal volume and alveolar ventilation not only raise the possibility of volutrauma, could also lead to

hypocarbia with its recognized deleterious effects on cerebral blood flow (6).

Hypoventilation due to insufficient tidal volume delivery due to increased resistance, airway obstruction can lead to inefficient gas exchange, increased work of breathing, agitation, increased risk of IVH. High inflation pressures or losses in alveolar volume due to insufficient ventilation can play a role in the development of lung injury in preterm infants.

It is now clear that volume is an important contributor to ventilator-induced lung injury (7), and as such, there is a growing interest in directly controlling tidal volume (*V*T) during mechanical ventilation in infants.

Volume targeted ventilation is a modality aimed at reducing the variability by adjusting the peak pressure or duration of the mechanical breath to maintain tidal volume (8). Modalities of volume targeted ventilation include volume controlled (VC), volume-assured pressure-support (VAPS), pressure-regulated volume-controlled (PRVC) and volume guarantee (VG) (8).

Volume guarantee (VG) is one such mode that may be combined with any standard synchronized mode such as SIPPV, SIMV or PSV mode. It is best described as a dual loop synchronized modality that ventilates with time cycled pressure limited ventilation but allows pressure to be adjusted to deliver a tidal volume in a clinician chosen range. The addition of volume guarantee to one of these modes enables the clinician to set a mean tidal volume to be delivered, as well as the standard ventilator settings of PIP, positive end expiratory pressure (PEEP), inspiratory time and respiratory rate. (8)

Our study aims to assess the effectiveness of addition of volume guarantee to SIPPV mode, in reducing the duration of ventilation in comparison to SIPPV mode of ventilation.

II. Material And Methods

Study Site: NICU Deenanath Mangeshkar hospital & research centre, Pune Maharashtra.
Study Population: Preterm infants admitted to NICU requiring mechanical ventilation.
Study Design: A prospective, randomized, comparative study
Sample Size with Justification: A sample size of 23 patients per group is needed to detect a reduction of 60% in mean duration of ventilation in preterm infants receiving SIPPV + Volume Guarantee (SIPPV+VG) mode of ventilation (36 hrs) compared to group of preterm infants receiving SIPPV mode of ventilation, with 80% power and 5% level of significance using a two-sample t-test (one tailed), assuming a mean duration of ventilation to be 96 ± 80 hrs in SIPPV group reported from the literature.
Articles cited for estimation of sample size:
Nuray Duman, Funda Tuzun, Sumer Sutcuoglu, Cemile Didem Yesilirmak, Abdullah Kumral & Hasan Ozkan. Impact of volume guarantee on synchronized ventilation in preterm infants: a randomized controlled trial. Intensive Care Med. (2012)38:1358-1364. (9)
Formula for estimating sample size with substitution of values used:
$nA=(1+1/\kappa)[\sigma(z\alpha+z1-\beta)/(\mu A-\mu B)]^2$
Where

- $\boldsymbol{\kappa}=n_A/n_B$ is the matching ratio **=1**
- σ is standard deviation = **± 80 hrs**
- β is Type II error, meaning 1−β is power; $\mathbf{Z_{1-\beta}}$ = Represents the desired power (typically **0.84** for **80% power**).
- α is Type I error =**5% ;** $\mathbf{Z_{\alpha}}$ = Represents the desired level of statistical significance (typically **1.64 for one tailed test**)
- difference in means = (μA−μB) **= 96- 36 hrs**

Time Frame to Address the Study: May 2016 – April 2017.
Inclusion Criteria:

1. Preterm babies of gestational age less than 37 wks requiring mechanical ventilation.

Exclusion Criteria:

1. Major congenital cardiac, respiratory or central nervous system malformation
2. Craniofacial malformations
3. Intraventricular hemorrhage, grade III/IV.
4. Pulmonary hemorrhage

46 consecutive preterm infants (of consenting parents) requiring mechanical ventilation were studied for duration of ventilation during the 1 year period from 01/05/16 to 30/04/17 in NICU of Deenanath Mangeshkar Hospital & Research center.
Out of 46 infants, 23 were put to SIPPV+VG mode of ventilation and 23 infants were put on SIPPV mode of ventilation.
Mode of ventilation was assigned based on computer generated random sequence numbers.

Babies were weaned to SIMV+VG/SIMV (As per respective initial mode) .
Extubation criteria were:

1. FiO2 ≤ 0.4,
2. Rate ≤ 20/min,
3. PIP ≤ 18cm H2O, or to achieve tidal volume 4-6 ml/kg,
4. PEEP ≤ 5cmH2O and
5. Flow of 6-8 L/min.
6. pH> 7.25, pCO2 ≤ 50

Babies were extubated to nCPAP.
Successful extubation was defined as no need of reintubation for at least 3 days after the first extubation attempt. The reintubation criteria, extubation failure were same in both the groups and include at least one of the following: Silverman-Anderson Score >7 (99), pH <7.25, pCO2 > 60 mmHg, SpO2 < 88% on FiO2 > 60%,
OUTCOME:
Primary Outcome: Duration of ventilation
Secondary Outcome:

1. Re intubation rate
2. Duration of CPAP
3. Duration of Oxygen requirement

STATISTICAL METHOD:

Statistical analysis was carried out with the help of SPSS (version 20) for Windows package (SPSS Science, Chicago, IL, USA). The description of the data was done in form of mean +/- SD for quantitative data while in the form of % proportion for qualitative (categorical) data. *P*-values of < *0.05* were considered significant. For quantitative data, Unpaired Student's t-test was used to test statistical significance of difference between two independent group means with respect to growth in terms of weight gain, duration of feeding and time to discharge between two independent groups. For comparison of categorical variables (i.e to examine the associations between qualitative/quantitative variables), chi-square test was used if the number of elements in each cell were 5 or higher and Fisher's exact test, otherwise. To compare proportions between two treatment groups or between pre & post treatment within a group, Z test of proportions was used.

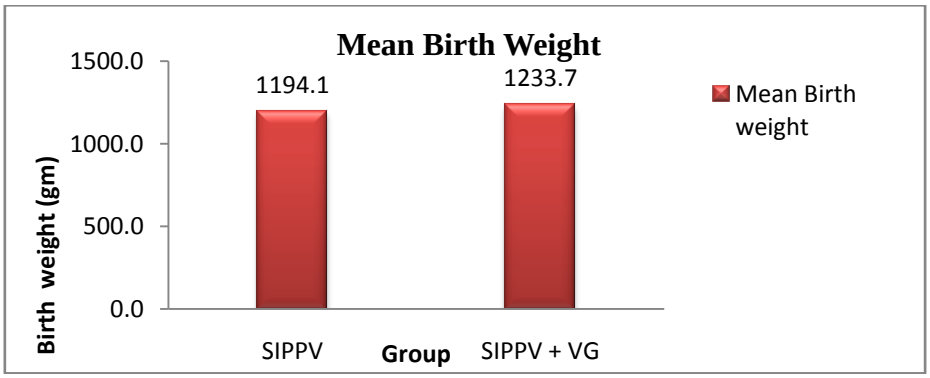
III. Observations And Results

Our study was conducted over period of 1 year from May 2016 to April 2017 in our level III b NICU at a tertiary care hospital. Total 46 preterm newborns requiring mechanical ventilation after birth were included in our study. Out of those, 23 neonates received SIPPV mode of ventilation and other 23 received SIPPV + VG mode of ventilation.

Out of 46 enrolled neonates in the study, 18 (39.13%) were female [8 (34.78%) in SIPPV group & 10 (43.48%) in SIPPV + VG group]. 28 preterm neonates (60.87%) were male in our study [15 (65.22%) in SIPPV group & 13 (56.52%) in SIPPV + VG group]. P value 0.763.

Table 1: Mean Birth Weight wise distribution of preterm neonates in both groups

Group	Number of patients	Birth weight (grams)		p-value
		Mean	SD	
SIPPV	23	1194.1	513.8	0.569
SIPPV + VG	23	1233.7	481.0	



Graph 1: Bar-Diagram showing mean Birth Weight wise distribution of preterm neonates in both groups.

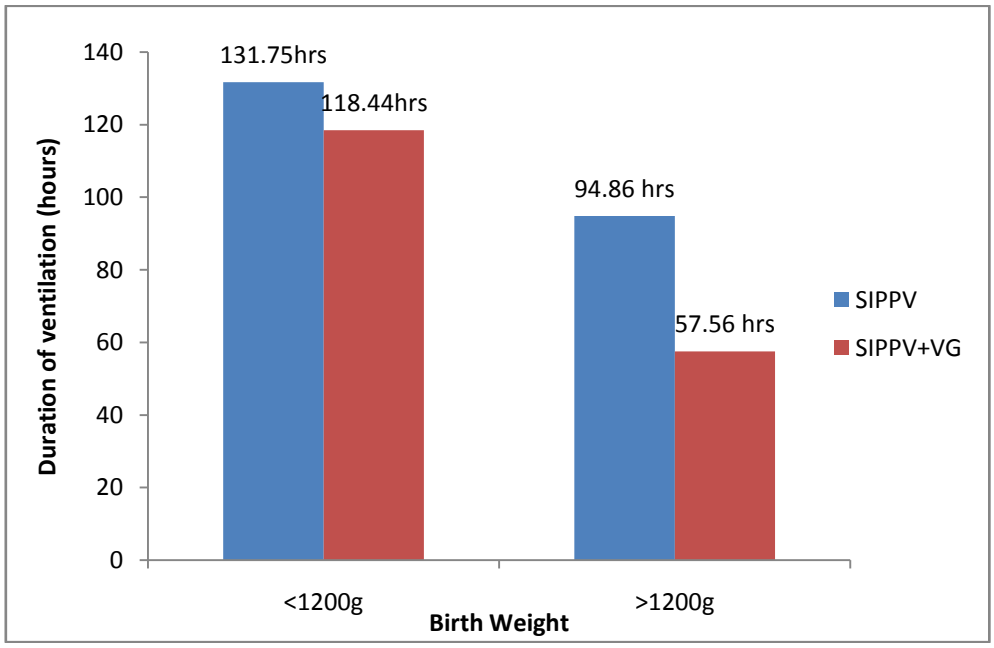
Conclusion:- By using Mann-Whitney U test p-value > 0.05, therefore there is no significant difference between SIPPV group and SIPPV + VG group regarding birth weight (gm).

3 neonates (13.04%) died in both Non VG and VG group. P value 0.999

Table 2: Mean required duration of ventilation in both groups according to Birth weight

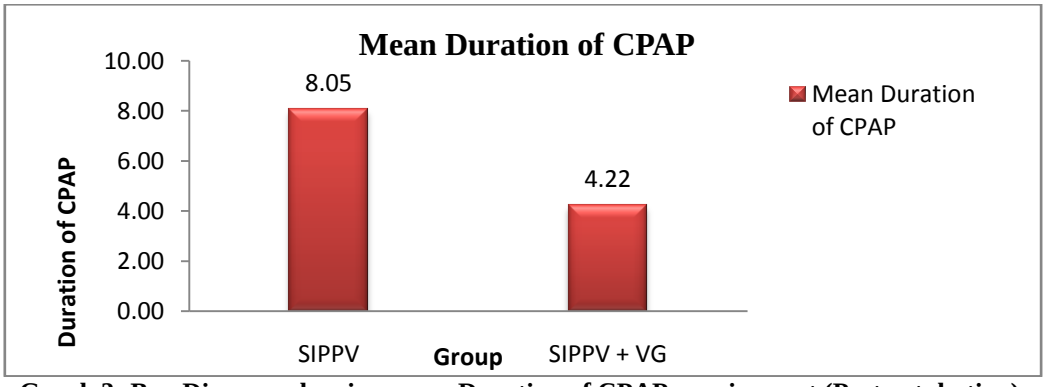
Birth Weight	Group	Required duration of Ventilation (hours)		P value
		Mean	SD	
Less than 1200g	**SIPPV**	131.75	73.48	0.862
	SIPPV+VG	118.44	59.35	
More than 1200g	**SIPPV**	94.86	46.79	0.071
	SIPPV+VG	57.56	51.39	

Mean required duration of ventilation in < 1200g birth weight infants was 131.75 hours (SD 73.48) in SIPPV group and 118.44 hours (SD 59.35) in SIPPV + VG group, p value 0.862.
Mean required duration of ventilation in > 1200g birth weight infants was 94.86 hours (SD 46.79) in SIPPV group and 57.56 hours (SD 51.39) in SIPPV + VG group, p value 0.071.



Graph 2: Bar-Diagram showing mean required duration of ventilation in both groups according to Birth weight.

Conclusion:- By using 2 independent sample t-test p-value > 0.05 therefore there is no significant difference between SIPPV group and SIPPV + VG group for required duration of ventilation.



Graph 3: Bar-Diagram showing mean Duration of CPAP requirement (Post extubation).

Mean duration of CPAP requirement in SIPPV group was 8.05 days (SD 5.59) while in SIPPV + VG group mean duration of CPAP requirement was 4.22 days (SD 2.84), p value 0.013.

Conclusion:- By using 2 independent sample t-test p-value < 0.05, therefore there is significant reduction in required duration of CPAP (post extubation) SIPPV + VG group compared to SIPPV group.

Table 3: Mean required duration of CPAP (Post extubation) in both groups according to Birth weight

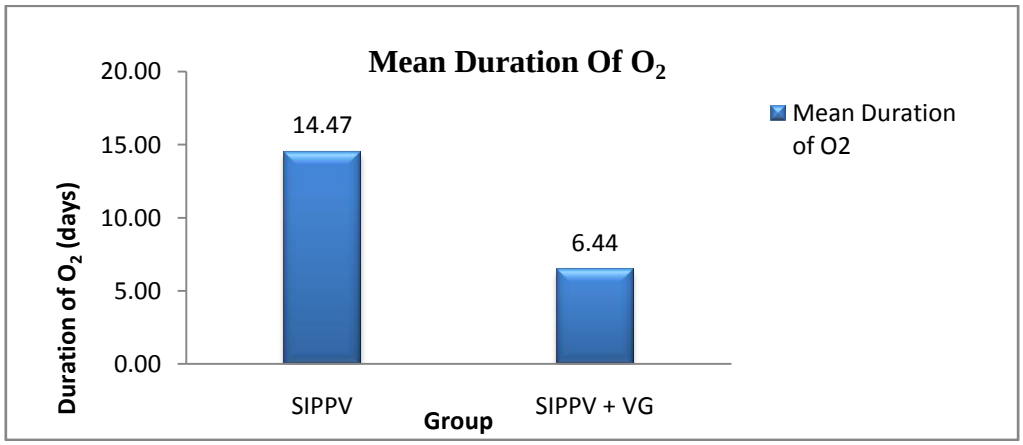
Birth Weight	Group	Duration of CPAP requirement (days)		P value
		Mean	SD	
Less than 1200 g	**SIPPV**	10.50	5.16	0.028
	SIPPV+VG	5.89	3.18	
More than 1200g	**SIPPV**	3.86	1.952	0.140
	SIPPV+VG	2.56	0.882	

In patients with birth weight < 1200 gram, mean duration of CPAP requirement in SIPPV group was 10.50 days (SD 5.16) while in SIPPV + VG group it was 5.89 days (SD 3.180), p value 0.028.
In patients with birth weight > 1200 gram, mean duration of CPAP requirement in SIPPV group was 3.86 days (SD 1.952) while in SIPPV + VG group it was 2.56 days (SD 0.882), p value 0.140 .

Table 4: Mean duration of Oxygen requirement in both groups

Group	No. of patients	Duration of O2 (days)		p-value
		Mean	SD	
SIPPV	19	14.47	10.66	0.013
SIPPV + VG	18	6.44	7.85	

In SIPPV group mean duration of O2 requirement was 14.47 days with SD of 10.66.
In SIPPV + VG group mean duration of O2 requirement was 6.44 days with SD of 7.85, p value 0.013.



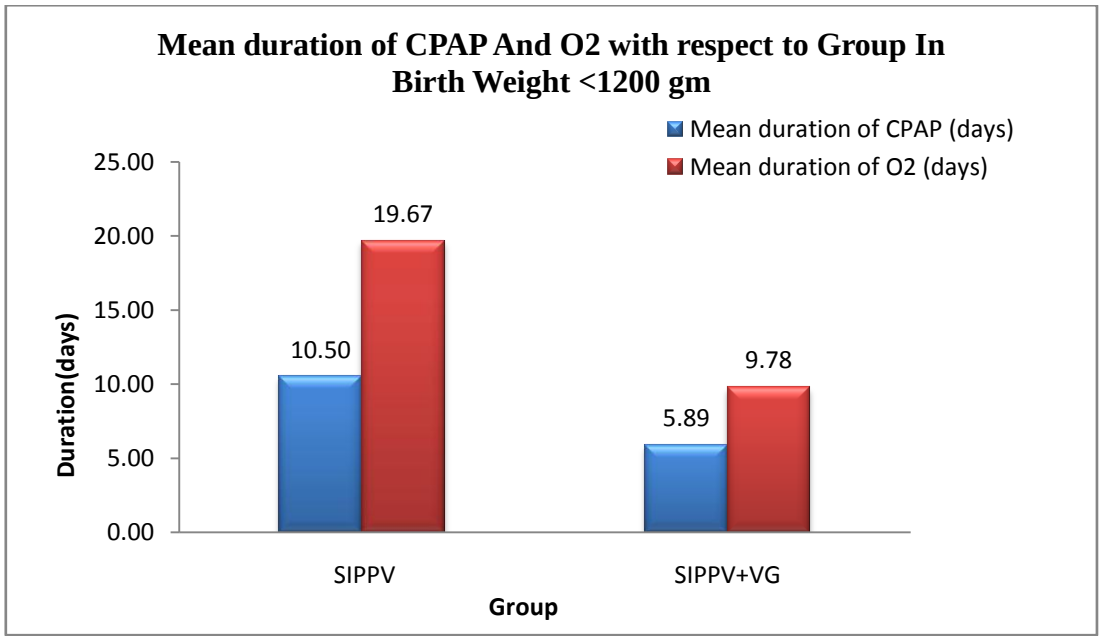
Graph 4: Bar-Diagram showing mean duration of Oxygen requirement in both groups.

Conclusion:- By using 2 independent sample t-test p-value < 0.05 therefore there is significant reduction in duration of O2 requirement in SIPPV + VG group compared to SIPPV group.

Table 5: Mean duration of Oxygen requirement in both groups according to birth weight

Birth Weight	Group	Duration of O2 (days)		P value
		Mean	SD	
Less than 1200g	**SIPPV**	19.67	9.727	0.035
	SIPPV+VG	9.78	9.833	
More than 1200g	**SIPPV**	5.57	4.577	0.249
	SIPPV+VG	3.11	3.060	

In patients with birth weight < 1200 gram, in SIPPV group mean duration of O2 requirement was 19.67 days (SD 9.727) while in SIPPV + VG group, it was 9.78 days (SD 9.833), p value 0.035.
In patients with birth weight > 1200 gram, in SIPPV group mean duration of O2 requirement was 5.57 days (SD 4.577) while in SIPPV + VG group, it was 3.11 days (SD 3.060), p value 0.249.



Graph 5: Bar-Diagram showing Comparison of required duration of CPAP and duration of Oxygen requirement between both groups in birth weight < 1200 g.

Conclusion:- By using 2 independent sample t-test p-value < 0.05 therefore there is significant reduction in mean duration of CPAP requirement and duration of O2 requirement in SIPPV + VG group and SIPPV group for patients with birth weight < 1200g.

IV. Discussion

As a result of therapeutic and technological advancements in neonatology, survival of extremely premature infants has increased substantially. Respiratory support in the neonatal intensive care unit continues to evolve rapidly. Despite a shift towards non-invasive respiratory support, 64% of neonates born less than 1200 gm require mechanical ventilation during their NICU stay (10).

Our study was conducted in a tertiary level III b NICU. Forty six preterm infants with respiratory distress, requiring mechanical ventilation fulfilling inclusion and exclusion criteria were enrolled in our study. Both groups (SIPPV and SIPPV + VG) were well – matched regarding baseline characteristics i.e. birth weight, gestational age, gender, mode of delivery, requirement of resuscitation at birth, surfactant requirement and requirement of pharmacological closure of patent ductus arteriosus (PDA).

Length of mechanical ventilation:

Nuray Duman et al (11) did randomize control trial to find the impact of VG on synchronized mode of ventilation. PLV Vs VG was compared and was found that required duration of ventilation was less in VG group [79 hrs in PLV group Vs 39 hrs in VG group, p 0.19]. Another study by Guven et al (12) showed reduction in duration of mechanical ventilation when VG ventilation in combination with surfactant treatment was used in preterm infants with RDS. A trend towards decrease in duration of ventilation in VG group was also observed in a randomized control study done by M. T. Khashaba et al (13).

WanSheng Peng et al (14) did systematic review and meta-analysis to assess the effect of volume-targeted ventilation (VTV) compared with pressure-limited ventilation (PLV) in preterm infants. Meta-analysis of nine trials (15, 16, 17-19, 9, 12, 20, 21) showed that preterm infants ventilated using VTV modes had significant reduction in duration of mechanical ventilation (mean difference −2.0 days). However, significant heterogeneity was reported between the trials.

We compared effect of SIPPV and SIPPV+VG group on the duration of ventilation. We did not find significant difference between the groups (118.16±66.06 hours in SIPPV group Vs 88.0±62.3 hrs in SIPPV+VG group, p value 0.169). On subgroup analysis, no significant difference was found between both the groups in babies less than 1200gm . Overall a consistent trend towards reduction in required duration of ventilation was observed in SIPPV + VG group. Our results were similar to the finding of the study done by Nuray Duman et al (11) and M. T. Khashaba et al (13).

Extubation Failure:

In the study done by M. T. Khashaba et al (13), preterm infants with RDS were ventilated with SIMV + VG & PSV + VG and compared with SIMV & PSV. They found that extubation failure was significantly less in VG group. Data reporting the failure of the primary mode of ventilation in VTV and PLV groups are described in four trials (16, 17, 19, 22) in the meta analysis done by Wan Sheng Peng et al in 2014 (14). The meta-analysis demonstrated that preterm infants treated with VTV had a significantly lower failure of primarily assigned mode of ventilation compared to those treated with PLV. In our study, extubation failure was noted in lesser frequency (4.35%) in SIPPV + VG group than in SIPPV group (13.04%). Although the incidence of extubation failure was less in VG group in our study, the difference found was not significant. The results obtained in our study are similar to the findings of study done by M. T. Khashaba et al (13).

Duration of CPAP (Post extubation):

Trials on volume guarantee ventilation have shown inconsistent results on required duration of CPAP (post extubation) in preterm infants. The randomized study done by Khashaba et al (13) showed the reduction in post extubation CPAP duration when volume guarantee ventilation was used. Sirin Guven et al (12) in their randomized controlled study found the significant reduction in duration of CPAP (days) in non VG group. In their study, duration of CPAP was significantly higher in SIMV+VG group compared with SIMV group. This can be explained with faster extubation rates after surfactant replacement in infants in SIMV+VG group.

In our study, post extubation duration of CPAP requirement in SIPPV + VG group was significantly less than in SIPPV group (8.05±5.59days in SIPPV group Vs 4.22 ±2.84 days in SIPPV + VG group, p value 0.013). On subgroup analysis, the duration of CPAP in babies with birth weight <1200gm was significantly less in SIPPV + VG group compared to SIPPV group. Similar trend was observed in babies with birth weight>1200gm. However, the difference found was statistically not significant.

Duration of oxygen requirement:

Clinical studies showed evidence of decrease in lung inflammation and rates of BPD with restricted use of oxygen or lower saturation targets (23, 24).

Guven et al (12) and Liu Cui-Qing et al (20) in their randomized controlled study observed significant reduction in duration of supplemental oxygen administration when preterm infants were ventilated with VG mode.

In pooled meta-analysis done by WanSheng Peng et al (14), data reporting supplemental oxygen administration in VTV and PLV groups are described in two trials (12, 22). The meta-analysis revealed reduced supplemental oxygen administration using VTV [MD of −1.68 (−2.47 to −0.88) days] compared to PLV.

In our study in SIPPV group mean duration of Oxygen (O_2) requirement was significantly less in SIPPV + VG group (14.47±10.66 days in SIPPV group Vs 6.44±7.85 days in SIPPV+VG group, p value 0.013). On subgroup analysis, we found that duration of O_2 requirement was significantly less in patients with birth weight<1200gm in SIPPV +VG group. Similar trend was observed in patients with birth weight>1200gm and but the difference found was statistically not significant.

These finding are in agreement with the findings of studies done by Liu Cui-Qing et al (20) and Guven et al (12). The obtained results in our study are also similar to the results of a meta-analysis done by WanSheng Peng et al (14).

V. Conclusion

We found that the infants, ventilated with VG mode of ventilation, required less duration of ventilation in comparison to infants ventilated with SIPPV mode. However, the difference found was statistically not significant.

Incidence of extubation failure is lesser in infants ventilated with SIPPV + VG mode of ventilation in comparison to the other group. Here also, we did not find the difference statistically significant.

Required duration of nasal CPAP in post extubation period, duration of oxygen requirement was found to be significantly less in SIPPV + VG group of infants in comparison to SIPPV group of infants in our study. The significant difference was mainly observed in infants of birth weight<1200gm .

Volume guarantee ventilation can be used for preterm infants for reducing the required duration of ventilation, post extubation nasal CPAP and oxygen days. By reducing the duration of ventilation, CPAP & Oxygen days in smaller premature infants, volume guarantee ventilation can be helpful in reducing the overall hospital stay in these infants.

References

[1]. Sekar KC. Trends in conventional mechanical ventilation and pulmonary graphics in the newborn. Chin Med J 2010; 123: 3319–3325.
[2]. Keszler M. State of the art in conventional mechanical ventilation. J Perinatol 2009; 29: 262–275.
[3]. Giuliani R, Mascia L, Recchia F, Caracciolo A, Fiore T, Ranieri VM. Patient-ventilator interaction during synchronized intermittent mandatory ventilation . Effects of flow triggering . Am J Respir Criti Care Med. 1995 Jan; 151(1):1-9.
[4]. Hummler H, Schulze A. New and alternative modes of mechanical ventilation in neonates . Semin Fetal Neonatal Med . 2009 Feb 28 (Vol. 14, No. 1, pp. 42-48) . WB Saunders.
[5]. Choukroun ML, Llanas B, Apere H, Fayon M, Galperine RI, Guenard H et al. Pulmonary mechanics in ventilated preterm infants with respiratory distress syndrome after exogenous surfactant administration: a comparison between two surfactant preparations. Pediatr Pulmonol. 1994 Nov 1; 18(5):273-8.
[6]. Wyatt JS, Edwards AD, Cope M, Delpy DT, McCormick DC, Potter A et al. Response of cerebral blood volume to changes in arterial carbon dioxide tension in preterm and term infants. Pediatr Res. 1991 Jun 1; 29(6):553-7.
[7]. Dreyfuss D, Saumon G. Ventilator-induced lung injury: lessons from experimental studies. Am J Respir Criti Care Med. 1998 Jan 1; 157(1):294-323.
[8]. Goldsmith JP, Karotkin E. Assisted ventilation of the neonate. Elsevier Health Sciences; 2010 Sep 28.
[9]. Lista G, Colnaghi M, Castoldi F, Condo V, Reali R, et al. Impact of targeted-volume ventilation on lung inflammatory response in preterm infants with respiratory distress syndrome (RDS). Pediatr Pulmonol. 2004 Jun 1; 37(6):510-4.
[10]. Soll R.Vermont Oxford Network Annual Data, Annual Report . Burlington, VT: Vermont Oxford Network; 2008
[11]. Duman N, Tuzun F, Sutcuoglu S, Yesilirmak CD, Kumral A, Ozkan H. Impact of volume guarantee on synchronized ventilation in preterm infants: a randomized controlled trial. Intensive Care Med. 2012 Aug 1; 38(8):1358-64.
[12]. Guven S, Bozdag S, Saner H, Cetinkaya M, Yazar AS, Erguven M. Early neonatal outcomes of volume guaranteed ventilation in preterm infants with respiratory distress syndrome. J Matern Fetal Neonatal Med. 2013 Mar 1; 26(4):396-401.
[13]. Khashaba MT, El-Mazahi MM, Nasef NA, Salam MA, Moussa NA. Volume guarantee ventilation in the weaning phase of preterm infants. Egyptian Pediatric Association Gazette. 2015 Dec 31; 63(3):86-90
[14]. Peng W, Zhu H, Shi H, Liu E. Volume-targeted ventilation is more suitable than pressure-limited ventilation for preterm infants: a systematic review and meta-analysis. Arch Dis Child Fetal and Neonatal Ed. 2014 Mar 1; 99(2):F158-65.
[15]. Keszler M, Abubakar K. Volume guarantee: stability of tidal volume and incidence of hypocarbia. Pediatr Pulmonol. 2004 Sep 1; 38(3):240-5.
[16]. D'Angio CT, Chess PR, Kovacs SJ, Sinkin RA, Phelps DL, Kendig JW, et al. Pressure-regulated volume control ventilation vs synchronized intermittent mandatory ventilation for very low-birth-weight infants: a randomized controlled trial. Arch Pediatr Adolesc Med. 2005 Sep 1; 159(9):868-75.
[17]. Sinha SK, Donn SM, Gavey J, McCarty M. Randomised trial of volume controlled versus time cycled, pressure limited ventilation in preterm infants with respiratory distress syndrome. Arch Dis Child Fetal Neonatal Ed. 1997 Nov 1; 77(3):F202-5.
[18]. Piotrowski A, Sobala W, Kawczyński P. Patient-initiated, pressure-regulated, volume-controlled ventilation compared with intermittent mandatory ventilation in neonates: a prospective, randomised study. Intensive Care Med. 1997 Sep 1; 23(9):975-81.
[19]. Singh J, Sinha SK, Clarke P, et al: Mechanical ventilation of very low birth weight infants: Is volume or pressure a better target variable? J Pediatr 149:308-313, 2006.
[20]. Liu CQ, Cui Z, Xia YF, et al. Randomized controlled study of targeted tidal volume ventilation for treatment of severe neonatal respiratory distress syndrome. Chin J Contemp Pediatr 2011; 13:696–9.
[21]. Zhou XJ, Zhou YR, Hu DY, et al . Effects of different ventilation modes on the lung injury in infants with very low birth weight . Chin J Emerg Med 2007; 16:703–5.
[22]. Nafday SM, Green RS, Lin J, et al. Is there an advantage of using pressure support ventilation withvolume guarantee in the initial management of premature infants with respiratory distress syndrome? A pilot study. J Perinatol 2005;25: 193–7.
[23]. Payne, N.R.; LaCorte, M.; Karna, P.; Chen, S.; Finkelstein, M.; Goldsmith, J.P. et al Reduction of bronchopulmonary dysplasia after participation in the breathsavers group of the Vermont Oxford network neonatal intensive care quality improvement collaborative. Pediatrics 2006, 118, S73–S77.
[24]. Vento, M.; Moro, M.; Escrig, R.; Arruza, L.; Villar, G.; Izquierdo, I.; et al. Preterm resuscitation with low oxygen causes less oxidative stress, inflammation, and chronic lung disease. Pediatrics 2009, 124, e439–e449.

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