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Research Article

Anesthesia Workstation Versus Intensive Care Ventilator in Pediatric Cardiac Surgery, is there a Difference?

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Abstract

Background: Anaesthesia workstations have evolved over the period to have sophisticated computerized controls, with several modifications to the circle breathing system that can provide all advanced types of ventilatory support.

Aim: To compare pressure control ventilation- volume regulated (PCV-VG) mode of ventilation in anesthesia workstation (GE Avance CS²) and intensive care ventilator (GE Engström Carestation™) in patients undergoing pediatric cardiac surgery.

Methods: All patients undergoing pediatric cardiac surgery during this period were included in the study. PCV-VG mode was used in both ventilators. Data was collected in the OR (group-1) and ICU (group-2) ventilators and was divided into three parts: hemodynamic data, ventilation parameters, and arterial blood gas data. The Ventilation Index (VI) was calculated as: $PaCO_2$ x peak inspiratory pressure (PIP) x mechanical respiratory rate (RR) divided by 1,000. The Oxygenation Index (OI) was calculated as: mean airway pressure MAP x FiO_2 x 100 divided by PaO_2. A paired t-test was used to analyze statistical differences between the two ventilators.

Results: 30 patients were included in the study. Most of the hemodynamic, ventilation and blood gas parameter were comparable between two ventilators. CVP (8.61 ± 3.15, 5.8 ± 2.53) was significantly lower in group-1 ventilator ($p < 0.0001$). The mean airway pressure (7.91 ± 1.56, 8.70 ± 0.79) ($p < 0.019$), compliance (6.86 ± 6.23, 7.72 ± 6.30) ($p < 0.001$) and MAP (57.85 ± 15.85, 63.31 ± 18.62) ($p < 0.004$) were significantly higher in group-2 ventilator. There was no difference in ventilation and oxygenation indices (VI and OI) in two ventilators.

Conclusion: There is no difference in terms of ventilation and oxygenation indices and hemodynamic effects between anaesthesia workstation and ICU ventilator using pressure-controlled ventilation-volume regulated mode of ventilation.

Keywords: *Anesthesia Workstation; Intensive Care Ventilator; Pediatric Cardiac Surgery*

Introduction

Mechanical ventilation is an integral part of pediatric heart surgery. All surgeries are done under general anaesthesia and require ventilation in the operating room as well as early and late postoperative period depending upon the complexity of the surgery and anatomy. Major part of the ventilation is taken over by an intensive care ventilator which is well equipped to handle poor lung compliance and has a better synchronization with child own breaths [1].

The contemporary anaesthesia ventilators in the anaesthesia workstations by Dräger, Datex-Ohmeda and others integrate many advanced intensive care unit (ICU) - type ventilation features and can provide ventilation to the most challenging patients brought to the operating room. These anaesthesia ventilators have sophisticated computerized controls, have several modifications to the circle breathing system and can provide advanced types of ventilatory support [2].

We ought to compare a mode of ventilation in anesthesia workstation ventilator (GE Avance CS^2 workstation) with that of intensive care ventilator (GE Engström Carestation™), in patients undergoing pediatric cardiac surgery.

Aim of the Study

To compare pressure control ventilation- volume regulated (PCV-VG) mode of ventilation in anesthesia workstation (GE Avance CS^2) with intensive care ventilator (GE Engström Carestation™) in patients undergoing pediatric cardiac surgery.

Material and Methods

The study designed was an observational one conducted at Amrita Institute of Medical Sciences, Kochi from January to February 2018.

All patients undergoing pediatric cardiac surgery during this period were included in the study after obtaining informed consent and formal approval of concerned authorities.

A sample size of 30 children undergoing cardiac surgery under general anesthesia were recruited in the study.

Inclusion Criteria: All patients undergoing pediatric cardiac surgery during the study period.

Exclusion Criteria: Patients requiring ICU ventilator in the OR.

All patients undergoing pediatric cardiac surgery underwent a standard anesthetic management and Extracorporeal circulation (ECC). Midline sternotomy was done in all cases.

All patients were ventilated in the operating room (OR) (Group-1) using GE Avance CS^2 workstation and in the intensive care unit (ICU) (Group-2), GE Engström Carestation™ Ventilator was used. Ventilation parameters were standardized. PCV-VG mode was used in all patients in both the groups. Tidal volume (TV) used was 8ml/kg and appropriate respiratory rate was set to maintain near normal $PaCO_2$. Age appropriate inspiratory time (Ti) was set from 0.5 to 0.8, with I:E ratio of 1:2 to 1:2.5. Rise time was set at 150 milliseconds. Maximum peak airway pressure (P_{max}) was set at 30 mmHg. Appropriate FiO_2 was set depending on the protocol based on cardiac lesion. PEEP of 4 - 5 was applied depending on the hemodynamics and blood gases.

Data collection was done in group-1 after separation from the cardiopulmonary bypass (CPB) and achieving full hemostasis post protamine administration. A mean of two reading taken an hour apart was recorded. In group-2, data was recorded after settling the patient post transport from the OR. All the readings were noted under full controlled ventilation after adequate muscular paralysis. Again, a mean of two readings one hour apart was recorded.

Demographic data was collected along with surgery done. Surgical complexity was classified using RACHS-1 [3] score. Data was divided into three parts: hemodynamic data, ventilation parameters, and arterial blood gas data.

The Ventilation Index (VI) was calculated as: $PaCO_2$ x peak inspiratory pressure (PIP) x mechanical respiratory rate (RR) divided by 1,000. The Oxygenation Index (OI) was calculated as: mean airway pressure (MAP) x FiO_2 x 100 divided by PaO_2.

Data was analyzed using IBM-SPSS™ v21. Data was tabulated using mean and standard deviation. To analyze statistically significant differences between the two ventilators a paired t-test was used. The level of statistical significance was set at $p < 0.05$.

Results

In this study 30 patients were included in the study after satisfying the inclusion and exclusion criteria. Pressure control ventilation-volume regulated (PCV-VG) mode of ventilation in anesthesia workstation (Group-1) was compared with that of intensive care ventilator (Group-2), in patients undergoing pediatric cardiac surgery.

Age was divided into 3 groups, < 1 month, > 1month to < 12 months, and > 12 months. Surgical complexity was divided according to RACHS-1 [3] score. Data was analyzed using IBM-SPSS™ v21.

13.33% (4) were neonates < 1 month of age. 53.33% (16) were infants between > 1 month and < 1 year of age. 33.33% (10) were > 1 year of age. 66.66% (20) were males and 33.33% (10) were females.

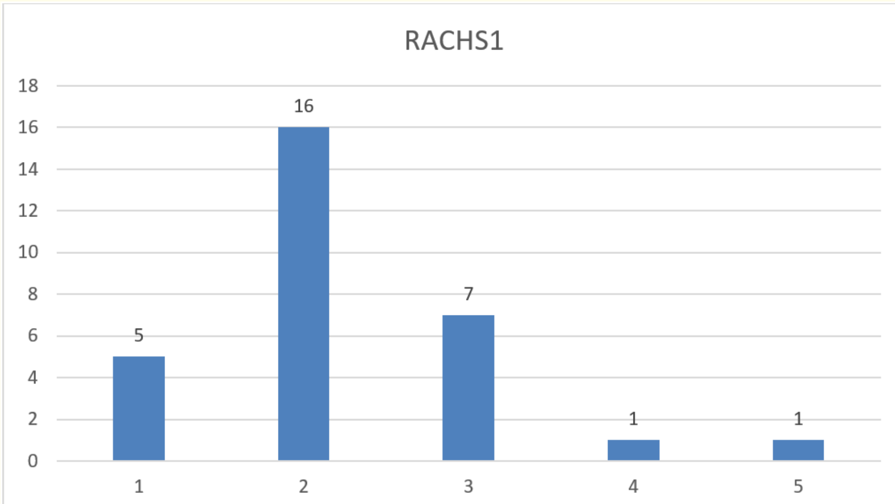

Figure 1: *RACHS1 surgical complexity score. 70% (21) of the cases were in RACHS1 category 1 and 2. 30% (9) were in RACHS1 3 to 5.*

Demographic Data	Mean ± SD	Median
Weight	10.70 ± 12.016	8.12
Height	80.27 ± 28.273	71.50
BSA	0.46 ± 0.309	0.40

Table 1: *Demographic data.*

	Group-1	Group-2	P-value
HR	135.66 ± 25.05	137.46 ± 20.22	0.584
MAP	57.85 ± 15.85	63.31 ± 18.62	0.004
CVP	8.61 ± 3.15	5.8 ± 2.53	< 0.001
SpO_2	97.75 ± 4.32	97.08 ± 4.50	0.394

Table 2: *Hemodynamic data showed mean MAP and CVP were significantly lower and higher respectively in group-1 as compared to group-2 ventilator.*

	Group-1	Group-2	P-value
TV	90.20 ± 82.95	90.98 ± 88.86	0.489
RR	27.28 ± 5.74	26.33 ± 6.08	0.026
MV	2.15 ± 1.37	2.14 ± 1.35	0.888
PIP	17.15 ± 2.59	17.06 ± 2.10	0.865
Pmean	7.91 ± 1.56	8.70 ± 0.79	0.019
PEEP	4.68 ± 0.84	4.98 ± 0.27	0.077
Compliance	6.86 ± 6.23	7.72 ± 6.30	0.001
Ti	0.71 ± 0.18	0.72 ± 0.18	0.831

Table 3: *Ventilation data showed mean respiratory rate was significantly higher in group-1 ventilator. The mean airway pressure and compliance were significantly higher in group-2 ventilator.*

	Group-1	Group-2	P-value
FiO_2	94.58 ± 14.94	73.33 ± 16.36	< 0.0001
PaO_2	215.53 ± 129.07	219.38 ± 113.88	0.825
$PaCO_2$	35.84 ± 5.75	36.41 ± 5.28	0.674
pH	7.373 ± 0.052	7.379 ± 0.046	0.564
Lactate	2.91 ± 1.65	2.95 ± 1.84	0.749
HCO_3	21.74 ± 1.69	21.27 ± 1.27	0.077
BE	2.72 ± 1.53	2.39 ± 1.95	0.225

Table 4: *In blood gas data, mean FiO_2 was significantly higher in group-1 ventilator.*

	Group-1	Group-2	P-value
VI	16.88 ± 5.69	16.21 ± 4.33	0.335
OI	5.16 ± 3.83	4.59 ± 4.30	0.185
PaO_2/FiO_2	227.78 ± 126.57	315.20 ± 157.16	< 0.0001

Table 5: *Derived values showed that there was no significant difference between two ventilators in terms of ventilation index and oxygenation index. The PaO_2/FiO_2 ratio was significantly better in group-2 ventilator.*

Surgical Procedure	n	%
Atrial Septal Defect Closure	5	16.7
Arterial Switch Surgery	1	3.3
Glenn Shunt	3	10
Glenn Shunt + Total Anomalous Pulmonary Venous Connection Repair	1	3.3
Ebstein Anomaly Repair + Ventricular Septal Defect Closure	1	3.3
Intra-cardiac Repair	5	16.7
Intra-cardiac Repair with RV to PA Conduit	2	6.7
Mitral Valve Repair	1	3.3
Norwood procedure	1	3.3
Partial Atrioventricular Canal Defect Repair	1	3.3
Ventricular Septal Defect Closure	7	23.4
Ventricular Septal Defect Closure + Coarctation of Aorta Repair	2	6.7
Total	30	100

Table 6: *Cardiac surgical procedures performed.*

Summary of Results

- 30 patients were included in the study.
- 13.33% (4) were neonates < 1 month of age. 53.33% (16) were infants between > 1 month and < 1 year of age. 33.33% (10) were > 1 year of age. 66.66% (20) were males and 33.33% (10) were females.
- Hemodynamic data showed mean MAP and CVP were significantly lower (p-0.004) and higher (p < 0.0001) respectively in group-1 as compared to group-2 ventilator.
- Ventilation data showed mean respiratory rate was significantly higher (p-0.026) in group-1 ventilator. The mean airway pressure (p-0.019) and compliance (p-0.001) were significantly higher in group-2 ventilator.

- In blood gas data, mean FiO_2 was significantly higher ($p < 0.0001$) in group-1 ventilator.
- Derived values showed that there was no significant difference between two ventilators in terms of ventilation index and oxygenation index. The PaO_2/FiO_2 ratio was significantly better ($p < 0.0001$) in group-2 ventilator.

Discussion

Pediatric cardiac surgery is evolving over the years with more and more complex congenital heart disease being offered surgery. These patients are often neonates with low birthweight, preterm or may have significant developmental anomalies of respiratory and cardiovascular system. There is need to protect these fragile lungs and airway during anesthesia care and postoperative period. Most of the times an ICU ventilator is used in the operating room for management of neonates and small infants. This causes significant predicament for the anesthesia team as they are unable to used anesthetic gases and cannot ventilate using a reservoir bag, especially during the periods when lungs are evading the surgical field, to facilitate better exposure for the surgery [4]. Additionally, the ICU ventilators are more sensitive to trigger and often take lung manipulation as patient trigger and deliver additional breaths in the process [5]. Apart from this there is significant space constraint in the OR with anesthesia workstation, ICU ventilator and echocardiography machine all in the zone of the anesthesiologist giving the anesthetic care. Compared to OR, the pulmonary mechanics in terms of airways resistance and total lung compliance in ICU patients is rarely normal. ICU ventilators have, therefore, evolved to support respiration using such techniques as inverse ratio ventilation and high levels of PEEP, which are rarely required during routine anaesthesia. GE Engsröm Care station boast of all these feature and is a very safe and robust ICU ventilator [6].

Modern day anesthesia workstation is well equipped with newer modes of ventilation as well sophisticated anesthesia delivery system. We used GE Avance CS^2 in our operating room which enables us to deliver mechanical ventilation using wide range of modes ranging from conventional volume control to pressure control-volume regulated [7]. In recent years, dual-control modes have been introduced in an attempt to combine the attributes of volume ventilation with the attributes of pressure ventilation, to avoid both the high peak airway pressures of volume ventilation and also the varying TV that may occur with pressure ventilation. PCV- VG mode is a kind of dual-control ventilation that uses TV as a feedback control for continuously adjusting the pressure limit [8].

In this study we found that mean arterial pressure was higher and central venous pressure was lower with group-2 ventilators. Probable reason for this is recovery of the heart after CPB in the postsurgical unit with more stable hemodynamics as compare to the operating room. Similar rise in pressure in early postoperative period has been reported by João P., *et al.* [9] where they mentioned weaning of anaesthetic agents in the early postoperative period to cause the rise in pressures, pain, hypothermia to name a few. The drop in central venous pressure is well known in post cardiac surgical patients with rewarming from hypothermia and associated peripheral vasodilation in early postoperative care [9,10].

ICU ventilators are better equipped with leak compensation and are known to compensate for large air leaks from the lungs or around airway tubing in the ICU setting. Monitoring facilities on ICU ventilators are adapted to function in these unusual circumstances to prevent an excess of false alarms. In contrast there are multiple exposed connections which are subject to disconnection or misconnection, kinking, or obstruction in anaesthesia workstation, small leaks inherent to such systems make low flow anaesthesia difficult [11]. We found higher respiratory rate to maintain desired $PaCO_2$ in group-1 ventilators, this may be due the aforesaid reasons and additionally volume overload in the immediate post CPB time may make gas exchange little demanding.

Compliance of lungs decreases after institution of cardiopulmonary bypass. The PaO_2/FiO_2 ratio is also affected due to this. Both compliance and PaO_2/FiO_2 ratio improve over the period of time after an uneventful cardiopulmonary bypass run [12]. In our study we found better compliance and PaO_2/FiO_2 ratio in group-2 as compared to the group-1 ventilators. Additionally, higher FiO_2 is needed to tide over the early post bypass period, this may explain the need of higher FiO_2 in the group-1 ventilators.

We also found a significant rise in mean airway pressure in group-2 ventilators. Sternotomy with open chest is required for most of cardiac surgeries. This can affect the hemodynamics and respiratory variables. During chest closure the peak as well as mean airway pressure increase and there is a reduction in venous return causing transient hypotension [13]. Few of our readings in the group-1 were collected during the time of hemostasis when the chest was still open. Since the group-2 values were all taken after chest closure this may explain the rise in mean airway pressure.

Oxygenation and ventilation indices (OI and VI) are currently used to evaluate MV duration and/or the severity of ventilation disorders [14]. Oxygenation index is a better representative of oxygenation dysfunction, higher values (> 8) represent pulmonary dysfunction [15]. In our study we found no difference in oxygenation and ventilation indices of both the groups with both having OI of < 8.

Our study, we believe is the first of its kind to compare the use of PCV-VG mode of ventilation in anaesthesia workstation with that of ICU care station ventilator in pediatric cardiac surgical patients. Both the ventilators are comparable in terms of hemodynamic, OI, VI and changes in the arterial blood gases.

Limitations of the Study

Limitation of our study is small sample size, which was difficult to define in absence of any published data. Confounding factors of cardiac surgery on pulmonary mechanic like pulmonary arterial pressures were not recorded. Being a single centre study we had to use the available ventilators for comparison, result may not be representative for ventilators of different make and settings.

Conclusion

Mechanical ventilation in the modern day anaesthesia workstation is comparable to sophisticated intensive care ventilator in patients undergoing pediatric cardiac surgery. There is no difference in terms of ventilation and oxygenation indices in the two ventilators using pressure controlled ventilation-volume regulated mode of ventilation.

Conflict of Interest

None.

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