Institute of postgraduate childhood Studies
Medical Studies Department

Comparative Study of Different Methods of Mechanical Ventilation on Preterm Neonates

Thesis

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By

Dr. Hoda Gouda HusseiM.B.,B.Ch., M.Sc. Pediatrics

Supervised By :

Dr. / Gamal Sami Ali
Professor of Pediatrics
The vice president of Ain Shams university
for community and environmental affairs
Ain Shams University

Dr. / Hanan Abd-Allah El-Gamal
Prof. in Medical Studies Department institute of
Postgraduate Childhood studies
Ain Shams University

Dr. / Howida Hosny El-Gebaly
Prof. in Medical Studies Department institute of
Postgraduate Childhood studies
Ain Shams University

Dr. / Dalia Fathi El-Sherif
Lecturer of Pediatrics – Faculty of Medicine
Ain Shams University

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معهد الدراسات العليا للطفولة
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تحـــت إشـــراف

ا.د/ جمال سامى على
أستاذ طب الأطفال
ونائب رئيس الجامعة لشئون المجتمع والبيئة
جامعة ع س

ا.د/ حنان عبد الله الجمل
أستاذ طب الأطفال بقسم الدراسات الطبية للأطفال
معهد الدراسات العليا للطفولة

ا.د/ هويــدا حسنى الجبالــى
أستاذ طب الأطفال بقسم الدراسات الطبية للأطفال
معهد الدراسات العليا للطفولة

د/ داليا فتحى الشريف
مدرس طب الأطفال
كلية الطب جامعة ع س

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INTRODUCTION

Asynchrony between mechanical and spontaneous breaths in mechanically ventilated ,but spontaneously breathing neonates may lead to impaired ventilation and gas exchange or to pulmonary barotraumas . In addition asynchrony has been observed in association with increased variability of cerebral blood flow velocity which has been suggested as a risk factor in the pathogenesis of intraventricular hemorrhage in premature neonates ***(Richards et al ., 2007*****).**

Previous efforts to avoid asynchrony of spontaneous and mechanical breaths included overriding the infant's own respiratory rate by increasing the ventilator rate matching the ventilator settings with the infant's own inspiratory and expiratory time , and eliminating spontaneous respiratory efforts by muscle paralysis. However ,muscle relaxation may result in delayed weaning and acute respiratory or cardiovascular deterioration . Several ventilator systems capable of synchronized mechanical ventilation are now commercially available ***(Martin et al ., 2006)*** .

These systems are designed to either synchronize a preset number of mechanical breaths to the infant's spontaneous breathing pattern ,known as synchronized intermittent mandatory ventilation

(SIMV), or to deliver a mechanical breath each time as spontaneous effort occurs , known as assist/control (A/C) .Most of the investigators who have studied the effect of synchronized ventilation on gas exchange in neonates compared the A/C mode with conventional IMV ***(Sarkar and Donn 2007)*** .

This is not a meaningful comparison because A/C provided more ventilatory support than IMV. It is ,therefore , not surprising that they found increased minute ventilation , improved oxygenation , and decreased $paCo_2$ during the A/C mode . More recently improved oxygenation has been reported in premature infants when switching from IMV to SIMV , while keeping the rate and the peak inspiratory pressure (PIP)unchanged ***(Wells et al.,2005)***

To make the measurements obtained during the different modes of ventilatory support comparable , total ventilation during the synchronized modes of ventilation was kept the same as during the IMV mode. It was expected that with more mechanical ventilatory support the infants own respiratory drive would decrease . However, the exact balance between spontaneous and ventilator-generated ventilation for the different modes of ventilation is not known and is difficult to predict ***(Darnall et al ., 2006)*** .

It was also hypothesized that large blood pressure fluctuation may present during IMV secondary to non-synchronized breathing and fighting the ventilator and that these fluctuations would be reduced during A/C.

AIM OF WORK

The aim of this study was to determine and compare the effect of IMV, SIMV and A/C modes of mechanical ventilation on gas exchange (PH, PaO_2 , $PaCo_2$, HCO_3 and O_2 sat.), mean ABP and ventilation (tidal volume , mechanical minute ventilation and mean airway pressure) in preterm with RDS neonates.

REVIEW OF LITERATURE

PHYSIOLOGY OF NEONATAL RESPIRATION

Prenatal Respiration

Fetal breathing movements are detected by ultrasonography from llth weeks of gestation, the function and significance of fetal breathing is uncertain but it probably permits development, of the respiratory system and the fetus makes breathing movement about 70% of the time and this movement are irregular and have frequency of 40-70 cycle per minute, however the clinical value of assessing fetal breathing as an indicator of fetal distress is still undergoing investigation ***(Romero,2007)*** **.**

The first breath:

During vaginal delivery, intermittent compression of the thorax facilitates removal of lung fluid. Surfactant in the fluid enhances aeration of gas-free lung by reducing the surface tension, so lowering the pressure required to inflate the airless lung. The pressure required to inflate the airless lung are higher than those needed at any other period where they range from 10-50 cmH_2O for 0.5-1.0 sec. intervals compared with about: $4cmH_2O$ for normal breathing newborn. The stimuli responsible for its breath are multiple and include a fall in PaO_2 and pH and rise in $PaCO_2$ due to interruption of the placental circulation ***(Beresford et al.,2000)*** .

The following are important in initiating breathing:

1- Physical stimuli: as cold water or touching the baby can initiate respiration.

2- Chemoreceptors: An important stimulus initiating the onset of respiration is the asphyxia! changes which follow clamping of the cord.

3- CNS activity: respiratory centre activity may also be involved in the onset of respiration ***(Baumer,2000)*** .

Mechanics of ventilation in the newborn

During either spontaneous or assisted ventilation, a pressure gradient between the airway opening and the alveoli must exist in order to drive the flow of gas during inspiration and expiration. This airway pressure gradient is required to overcome the elastic properties of the lung parenchyma and chest wall as well as the resistance to air flow ***(McCallion et al.,2005)***

The necessary pressure gradient can be calculated from the following equation :

$$\textit{Pressure} = \frac{\textit{Volume}}{\textit{Compliance}} + (\textit{Resistance} \times \textit{flow})$$

Compliance:

Compliance (C_L) describes the property of elasticity or extensibility of the lungs and chest wall and is expressed as the change in volume per unit change in pressure, as follow:

$$\textit{Compliance}\ (C_L)\ (L/cmH_2O) = \frac{\Delta \textit{Volume}\ (L)}{\Delta \textit{Pressure}\ (cmH_2O)}$$

$$(C_L) = \Delta V/\Delta P$$

Therefore, the higher the compliance, the larger the delivered volume per unit of pressure. In neonates the chest wall is very distensible and does not contribute a substantial elastic load when compared with the lungs. In normal newborn infant the respiratory system compliance range from 0.003 to 0.006 L/cmH_2O ***(Thome and Carlo,2003)***.

Resistance:

Resistance is a property of the inherent capacity of the lungs to resist air flow and is expressed as change in pressure per unit change in flow, as follows:

$$\textit{Resistance } (cmH_2O/L/secJ = \frac{\Delta\ Pressure(cmH_2O)}{\Delta\ Flow\ (L/sec)}$$

Pressure needed to force gas through the airway (airway resistance) and exceed the vicious resistance of the lung tissue (tissue resistance) total (airway and tissue) pulmonary resistance values for normal newborn infants ranges from 20-40 cmH_2O/L/Sec. and are not markedly affected in newborn with RDS. Since the endotracheal tube adds resistance, values of total pulmonary resistance for intubated infants range from approximately 50-150 cmH_2O/L/Sec ***(O'Donnell and Parker.,2006)*** .

Airway resistance in both laminar (streaming smoothly) and turbulent (swirling irregularly) flow conditions is determined by

1- flow rate or velocity of air flow.

2- The length of conducting airways or tubes.

3- Physical properties (viscosity and density) of gas breathed.

4- Inner diameter of airway or tubes ***(Finner et al.,2004)***

Time constant:

Is used to describe the time necessary for an instantaneous or step change in airway pressure to equilibrate through the lungs and once pressure is equilibrated through the lungs no airflow no further volume change so it is defined as the product of resistance and compliance.

Time constant (Sec.) = **Resistance** (cmH_2O/L/Sec) x **Compliance** (L/cmH_20)

Three to five time constants are required to allow complete filling or emptying of an alveolar unit ***(Singh et al.,2006) .***

In normal infant one time constant equals to 0.15 sec. and three time constant equal 0.45 sec. So if inspiratory time is less than three to five time constant for a given step change in airway pressure, an incomplete tidal volume will be delivered.

And if the expiratory time is insufficient, expiration may not be complete leading to increase in the functional residual capacity and inadvertent positive end expiratory pressure (PEEP). So when time constant are long, as in meconium aspiration, care must be taken to set inspiratoiy times and rates that permit adequate inspiration to deliver the required tidal volume and adequate expiration to avoid inadvertent PEEP ***(Sarkar and Donn.,2007) .***

Work of breathing:

The work of breathing is the force or pressure generated to overcome the static-elastic and frictional resistance forces that oppose volume expansion and gas flow into and out of the lungs during respiration and the amount of work performed is dependent on the elastic properties of the lung and chest wall, airway resistance, the Vt size, and respiratory frequency.

In healthy infants at rest, a minimum of work is sufficient to overcome the elastic forces and airway resistance. However, in infants with alterations in respiratory compliance or airway resistance (or both), a considerable increase in work for breathing may be encountered ***(Singh et al., 2005)*** .

Pulmonary gas Exchange:

Ideally the ratio of alveolar ventilation (VA) in ml/min. to pulmonary capillary blood flow (Qc) in ml/min- the ventilation perfusion ratio is one. The value is 0.8-0.9 in normal adult lung and in newborn the value is lower specially during the 1st few hours of life . A right to left shunt is blood passing from the right to left side of the heart without being oxygenated ***(Strand et al.,2003)***.

There are four shunt sites in the newborn.

1- Cardiac veins draining into the left side of the heart and anastmoses between the bronchial and pulmonary circulation.

2- The foramen ovale and ductus arteriosus during postnatal circulation.

3- Intra-pulmonary shunting owing to pulmonary arterial blood going through the lung without passing a ventilated alveolus- this is true Intra-pulmonary shunt with a V/Qc of 0.

4- Intra-pulmonary shunting owing to partially ventilated alveoli having a lower PaO_2 than elsewhere in the lung. These causes V/Q ratio less than normal but greater than 0.

Table(1): Neonatal pulmonary physiology by disease stated (Roberton, 1993) .

Disease	Compliance ml/cmH_2O	Resistance ml/cm H_2O/S	Time constant (S)	FRC (ml/kg)	V/Q matching	Work
Normal term	4-6	20-40	0.25	30mL/kg	--	--
RDS	↓↓	--	↓↓	↓	↓/↓↓	↑
Meconium Apsiration	--/cc	↑/↑↑	↑	↑/↑↑	↓↓	↑
BPD	↑/↓	↑↑	↑	↑↑	↓↓/↓	↑↑
Air leak	↓↓	--/↑	--	↑↑	↓/↓↓	↑↑
VLBW apnea	↓	--	↓↓	--/↓	--	--/↑

Key: ↑↑= increase ↓= decrease -- = little or no change /= either/or

BPD= Bronchopulmoniy dysplasia.

A measurement of the size of the shunt is the A-a DO_2 (alveolar arterial oxygen gradient in mmHg) this is normally less than I5mmHg. The bigger this value, the bigger the shunt ***(Mourani et al.,2004)***.

Ventilation perfusion matching (V/Q)

Diseases that reduce alveolar surface area (e.g. atelectasis) permit intrapulmonary shunting of desaturated blood. The opposite occur in persistent pulmonary hypertension, when extrapulmonary shunting divert blood flow away from the ventilated lung. Both mechanisms result in systemic recirculation of desaturated blood ***(Oddo et al,2006).***