COMPARITIVE STUDY BETWEEN PRESSURE REGULATED VOLUME CONTROLLED MODE*(AUTOFLOW™) *VERSUS VOLUME CONTROLLED MODE DURING MECHANICAL VENTILATION OF* ACUTE LUNG INJURY (ALI) / ADULT RESPIRATORY DISTRESS SYNDROME (ARDS) *PATIENTS

Thesis

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In Anesthesiology

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ABSTRACT

The findings of the current study can be summarized as follows: 1) Auto-flow ventilation versus VCV had resulted in lower CVP together with higher CI and SI. 2) Blood gas analysis had demonstrated that when using auto-flow mode compared to VCV among patients with ALI/ARDS Ph was higher, $PaCO_2$ was lower and better oxygenation estimated through better PaO_2 and oxygen saturation. 3) Respiratory parameters measured had also demonstrated lower Pplat, higher tidal volumes and improvement in respiratory system compliance when auto-flow mode was used compared to VCV 4) Finally according to weaning criteria, patients ventilated with auto-flow had demonstrated higher success rate of weaning, however mortality rate and rate of re-intubation did not differ according to mode used and that patients successfully weaned had lower duration of mechanical ventilation.

Key ward :-

Autof low - volume costrolled ventilation lung cnsury

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List of abbreviation

ALI	Acute Lung Injury
ARDS	Adult Respiratory Distress Syndrome
AECC	American European Consensus Conference
BAL	Broncho Alveolar Lavage
Crs	Respiratory System Compliance
CPPB	Continous Positive Pressure Breathing
C inf	Inflation Compliance
C end	End Inspiratory Compliance
C def	Deflation Compliance
CPAP	Continous Positive Airway Pressure
COPD	Chronic Obstructive Pulmonary Disease
CO	Cardiac Output
CI	Cardiac Index
CVP	Central Venous Pressure
DBP	Diastoltc Blood Pressure
ECMO	Extra Corporeal Membrane Oxygenation
EF	Ejection Fraction
Fio_2	Fraction Of Inspired Oxygen
FRC	Functional Residual Capacity
HFOV	High Frequency Oscillatory Ventilation
HR	Heart Rate
IMV	Intermittent Mandatory Ventilation
ICU	Intensive Care Unit
LIS	Lung Injury Score
LIP	Lower Inflection Point
LVSWI	Left Ventricular Stroke Work Index
MBP	Mean Blood Pressure
PCV	Pressure Controlled Ventilation
PRVC	Pressure Regulated Volume Control
p plat	Plateau Pressure
PEEP	Positive End Expiratory Pressure
PIP	Peak Inspiratory Pressure
paw	Airway Pressure
pao_2	Arterial Oxygen Pressure
PV curve	Pressure Volume Curve
PAOP	Pulmonary Artery Occlusion Pressure
PAC	Pulmonary Artery Catheter
PBW	Predicted Body Weight
PLV	Partial Liquid Ventilation

RCT	Randomized Control Trial
RR	Respiratory Rate
RWMA	Regional Wall Motion Abnormality
SICU	Surgical Intensive Care Unit
SBT	Spontaneous Breathing Trials
SI	Stroke Index
SBP	Systolic Blood Pressure
SVRI	Systemic Vascular Resistence Index
TNF	Tumor Necrosis Factor
TFC	Thoracic Fluid Content
UIP	Upper Inflection Point
VCV	Volume Controlled Ventilation
VT	Tidal Volume
VILI	Ventilator Induced Lung Injury
VALI	Ventilator Associated Lung Injury
WOB	Work Of Breathing

Introduction

Traditional mechanical ventilation is provided either with a constant volume or pressure breath. Volume-controlled ventilation (VCV) and pressure-controlled ventilation (PCV) are not different ventilatory modes, but are different control variables within a mode. Debate over the optimal ventilatory mode continues so to do the debate over the optimal control variable. Volume-controlled ventilation offers the safety of a pre-set tidal volume and minute ventilation but requires the clinician to appropriately set the inspiratory flow, flow waveform, and inspiratory time. During Volume-controlled ventilation, airway pressure increases in response to reduced compliance, increased resistance, or active exhalation and may increase the risk of ventilator-induced lung injury. Pressure-controlled ventilation, by design, limits the maximum airway pressure delivered to the lung, but may result in variable tidal and minute volume. During pressure-controlled ventilation the clinician should titrate the inspiratory pressure to the measured tidal volume, but the inspiratory flow and flow waveform are determined by the ventilator as it attempts to maintain a square inspiratory pressure profile. Most studies comparing the effects of Volume-controlled ventilation and pressure-controlled ventilation were not well controlled or designed and offer little to our understanding of when and how to use each control variable (1-3). In recent years, dual-control has been introduced in an attempt to combine the attributes of volume ventilation (constant tidal and minute ventilation) with the attributes of pressure ventilation (rapid, variable flow and reduced work of breathing).

Patients with acute lung injury and acute respiratory distress syndrome (ALI/ARDS) frequently require mechanical ventilation to alleviate underlying hypoxia associated with the pathophysiological derangement of the disease. Mechanical ventilation can be associated with deleterious effects, not only on the cardiovascular system (4) but also on the respiratory system (5-7). Ventilator induced lung injury (VILI) can alter the alveolar capillary membrane in a manner similar to ARDS (6, 8) and results in activation of pulmonary inflammatory mediators (biotrauma) (8, 9) and may lead to a systemic inflammatory response (9, 10). VILI can be induced by overdistention of alveoli occurring at the end of inspiration related to excessive alveolar pressure (Volutrauma and barotrauma) (8, 11-14) and or repetitive collapse and reopening of airways and alveoli that fail to maintain patency at end of expiration (atelectotrauma) (15-21) are assumed to be the primary mechanism of VILI. Oxygen toxicity is also a well-appreciated component of lung injury, however the threshold or the time needed to develop toxicity are not well known, but logically the lower the concentration and the shorter the time in which high fractions are used the best provided that adequate arterial oxygenation is maintained.

Patients with ARDS are prone to the effects of VILI at several levels due to underlying pathology, thus extra caution should be exercised when ventilating these patients and hence the name " protective ventilatory strategy" which means a strategy, that allows acceptable gas exchange and at the same time protects against VILI in an attempt to improve outcome. Amato et al (22) was one of the first to show beneficial effects of protective ventilatory strategies in mortality rate of ARDS, however the results of his study was criticized because his control group had unexplained too high mortality rate. In 2000, the ARDS network (23) stopped its trial as the group receiving low tidal volumes had significant lower mortality rate than the group receiving high tidal volumes, and it was the first large multicenter study to show a benefit from any intervention in ARDS and many believed that the trial represent a significant advancement in understanding the optimal management of ARDS (24) and since then low tidal volumes became the standard ventilatory strategy. The corner stone of the low tidal volume strategy is not only using low tidal volume alone (4-8 ml/Kg PBW) but also maintaining lower plateau pressure (Pplat) (<30 cmH_2O) (23).

Thus if low tidal volume strategy will be used for management of such patients and clinician decided to use the volume control mode, he should set tidal volume between (4-8 ml/Kg PBW) and monitor plateau pressure. If at any given time Pplat is >30 cmH_2O the set tidal volume should be reduced accordingly to maintain the desired Pplat with a minimum of 4ml/kg PBW. By the same token if the pressure control mode used and was set within the desired pressure range, however volume can be variable; at some points <4ml/Kg PBW or even may be >8ml/Kg PBW and both volume targets are not desirable tidal volume range according to recommendations (23).

Dual control modes considers both pressure target and set tidal volume into consideration and can change quality of breath control within a narrow window of pressure . Thus theoretically such modes can be an attractive option for physicians dealing with ALI/ARDS to achieve an efficient low tidal volume strategy. Unfortunately there is no evidence whether such modes can be of value in such patient population. In this strategy we investigated the safety and efficacy of dual control modes (namely Auto-Flow ™) versus conventional volume controlled ventilation in patients with acute lung injury and acute respiratory distress syndrome (ALI/ARDS).

Review of Literature

In the following section the following issues will be discussed.

I. *Over view of Auto-Flow ™*

- Definition.
- Volume control versus Pressure control versus Auto-Flow.
- Potential benefits from using auto-flow mode.

II. *Acute lung injury and acute respiratory distress syndrome. (ALI/ARDS).*

- Discovery of ALI/ARDS.
- Definition of ALI/ARDS.
- Overview of ventilator induced lung injury (VILI).
- Highlighting the ARDS network, its trial and future investigations.
- Evidence based management of ALI/ARDS.

Definition of Auto-Flow

During Auto-Flow ventilation, inspiration is machine or patient triggered, pressure limited and machine or patient cycled. The unique aspect of auto-flow is that pressure limit is not constant, but varies from one breath to the next, based on a comparison of the set and delivered inspiratory tidal volume.

The logic for controlling the output of the current breath based on the previous breath has led this technique to be called dual-control breath-to-breath (25, 26). It is important to know that the ventilator can only control pressure or volume during a given breath but not both. So auto-flow is a pressure controlled inspiration with a volume target. It is called a target and not control because the tidal volume delivered may be higher or lower than planned, unlike volume control where tidal volume delivered is identical to set tidal volume.

Upon selecting auto-flow, the ventilator provides a test breath. This test breath can be at a constant pressure or volume. The test breath allows the total respiratory system compliance (Crs) to be measured. The algorithm (Figure 1) then can calculate the pressure required to deliver the tidal volume set by clinician. The ventilator may initially deliver 75-100 % of the calculated pressure. The tidal volume leaving the ventilator is then compared to the set tidal volume and the pressure on the subsequent breath is either held constant (if the set tidal volume met the delivered tidal volume) or adjusted (decrease if the delivered tidal volume is greater then the set tidal volume or increased if the delivered tidal volume is less than set tidal volume (Figure 2).

The ventilator limit the maximum change from one breath to next in a window of 3cmH_2O (i.e. ± 3cmH_2O). The minimum inspiratory pressure is typically positive end expiratory pressure (PEEP) plus 5 cmH_2O and the peak inspiratory pressure (PIP) is the high pressure alarm setting minus 5 cmH_2O. If the set tidal volume can not be delivered because of high pressure setting an alert is generated. This alert typically provides a message such as "volume not constant" so the clinician is aware that the desired tidal volume is not being delivered.

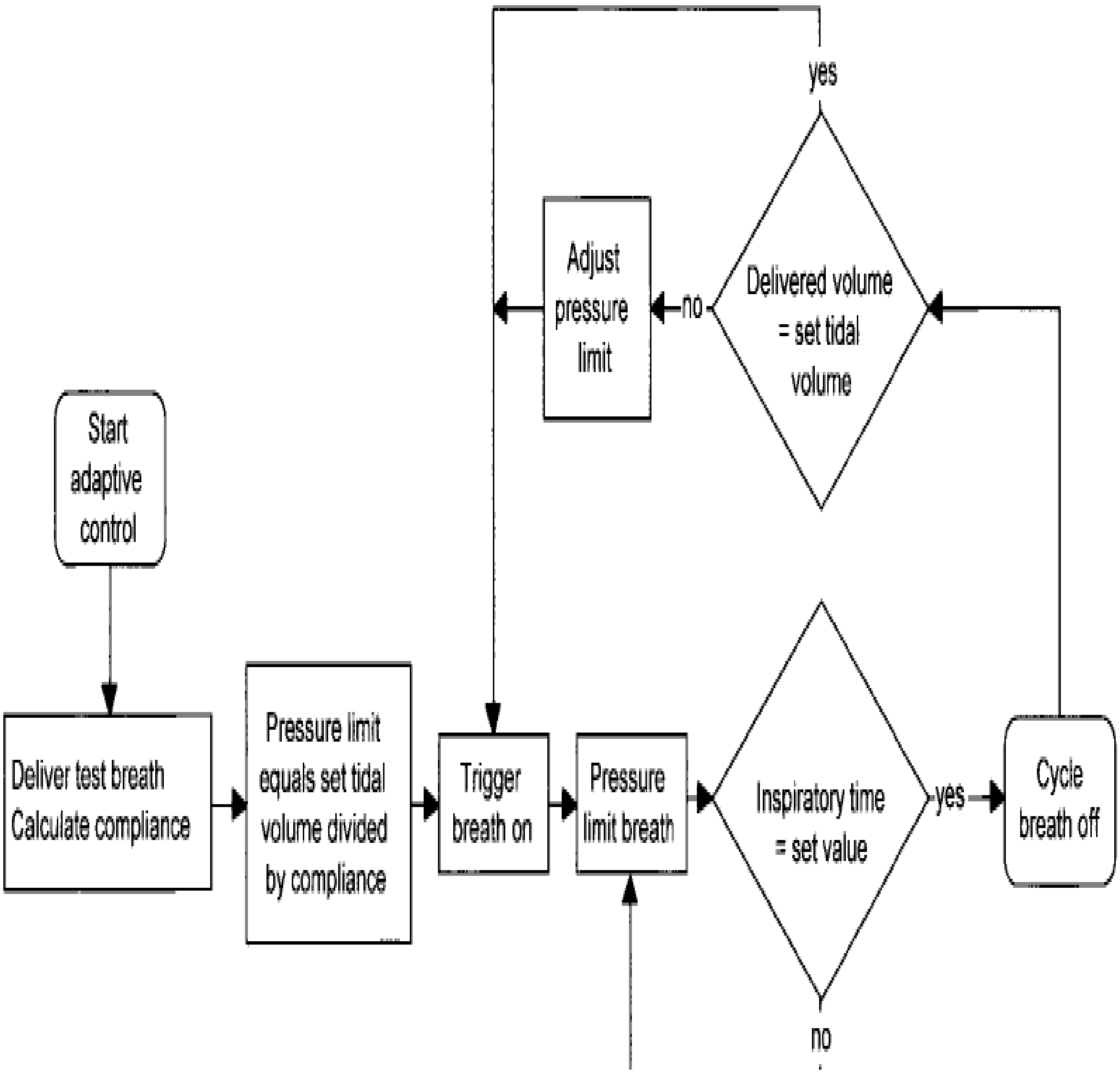

Figure 1 Operational algorithm for Auto-Flow on the Drager Evita 4 Ventilator (27).

Over view of Auto-Flow: Definition.

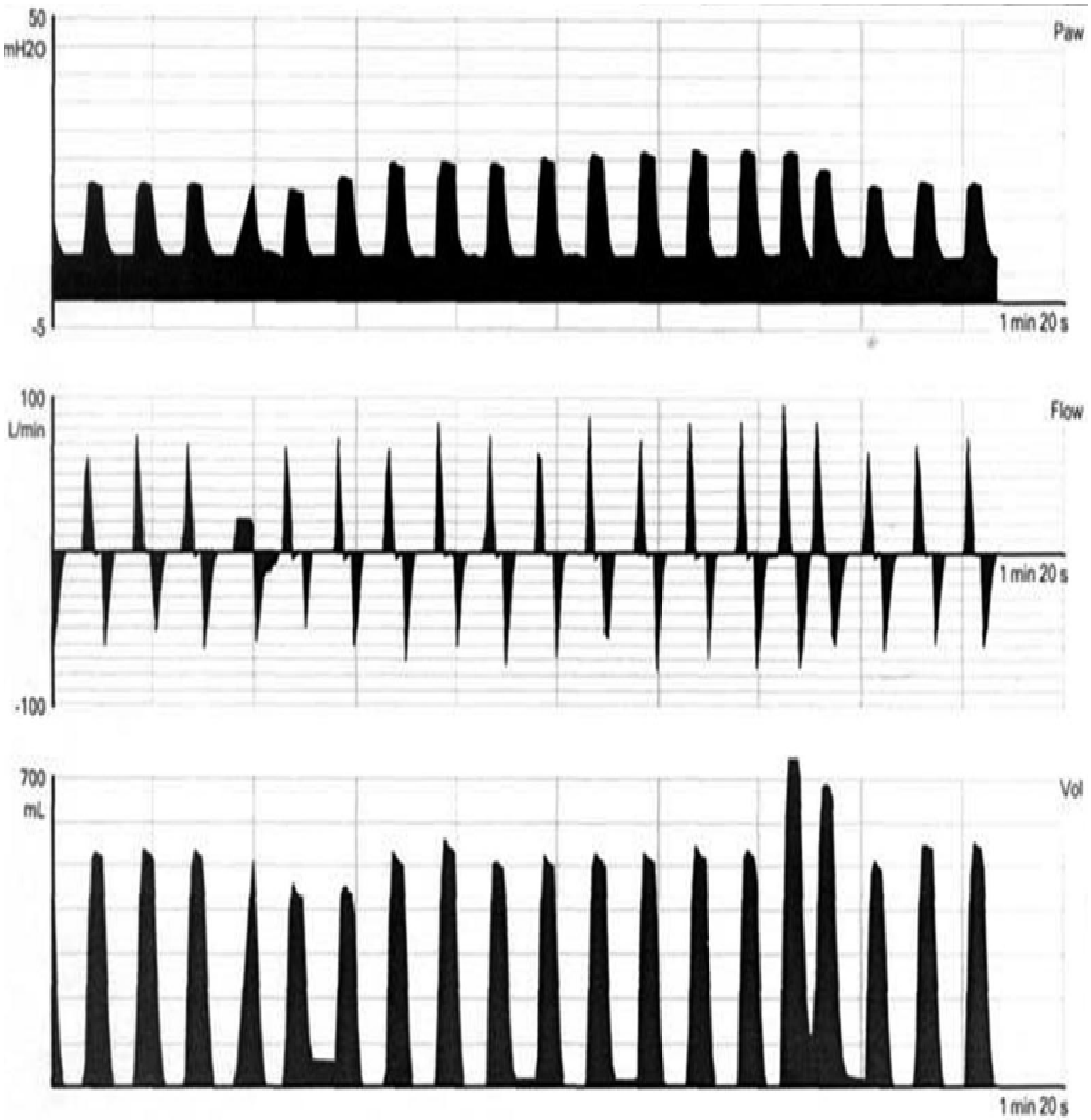

Figure 2 Wave forms from the implementation of Auto-Flow. The first 3 breaths are plain pressure controlled breaths. Auto-Flow is initiated and a test breath is delivered using volume control at a constant flow. Successive breaths use dual control breath to breath to increase airway pressure until target volume is reached. When compliance increases tidal volume exceeds target and the airway pressure is reduced over 3 breaths until tidal volume reach the target.

Volume control versus pressure control versus auto-flow.

Volume control provides a constant volume and variable airway pressure, and pressure control provides constant airway pressure and variable tidal volume, the goal of auto-flow mode is to provide a constant tidal volume through automatic adjustment of the pressure limit. So auto-flow is designed to combine the positive attributes of both volume and pressure control modes, the response to changes in patient condition can result in variable response with each breath. However, auto-flow can not guarantee a set tidal volume unlike volume control mode if the patient's respiratory system compliance is low enough and the high pressure alarm is set too low. Similarly auto-flow can not limit the inspired tidal volume beyond reducing the peak airway pressure. If the patient can generate an inspiratory pressure great enough, the delivered tidal volume may be greater than the set tidal volume. On the other hand if the patient makes no effort at all and the ventilator is set properly, the volume will not be less than the desired volume. Table 1 lists characteristics of the 3 breath types and response to common clinical conditions among the 3 modes.

Table (1) characteristics of volume control, pressure control and auto-flow modes and their response to common clinical conditions.

Variable	**Volume control**	**Pressure control**	**Auto-flow**
Tidal Volume	**Constant**	**Variable**	**variable**
PIP	**Variable**	**constant**	**variable**
Peak inspiratory flow	**constant**	**variable**	**variable**
Flow waveform	**constant**	**variable**	**variable**
Response to clinical conditions			