Modes (Moods) of Mechanical Ventilation

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This review will revolve (evolve) around the use of the Servo 300C which is the primary ventilator used in the PICU. This is an intermittent flow machine ie the patient must initiate ("trigger") the start of a new breath which requires the opening of an inspiratory flow valve. This is in contrast to the Bear Cub which is a continuous flow machine ie the patient is able to draw a breath from the gases flowing through the circuit. Since the advent of the 300C, the "triggering" of the breath has become much easier and more rapid in its response. This "triggering" function as well as the type of breath received for each different mode will be discussed later. If high frequency oscillatory or liquid ventilation becomes a "standard of care" in the unit, then additional information will be forthcoming but, in the meantime, only a discussion centering around the 300C will be made. I will first review the basics of what knobs to turn when attempting to affect pO_2 or pCO_2.

To Affect O_2	**To Affect CO_2**
FiO_2	RR
PEEP	TV (PIP)
I Time	

As you can see, there are only five (5) knobs to turn or orders to write when managing a patient on any conventional ventilator (along with the mode). You need to be aware of the patient's underlying pathophysiology in order to determine the "best" way to deliver the volume and at what rate. Many times this is discovered through trial and error at the bedside. An initial starting point is, however, important to know. Pressure Support settings will be discussed later since it is not considered that important in the initial settings.

Initial Settings

FiO_2 - 1.0 (100% O_2) for a patient with lung disease; 0.40 (40% O_2) for a patient without lung disease.

PEEP +6-8 for a patient with lung disease; +4 for a patient without lung disease.

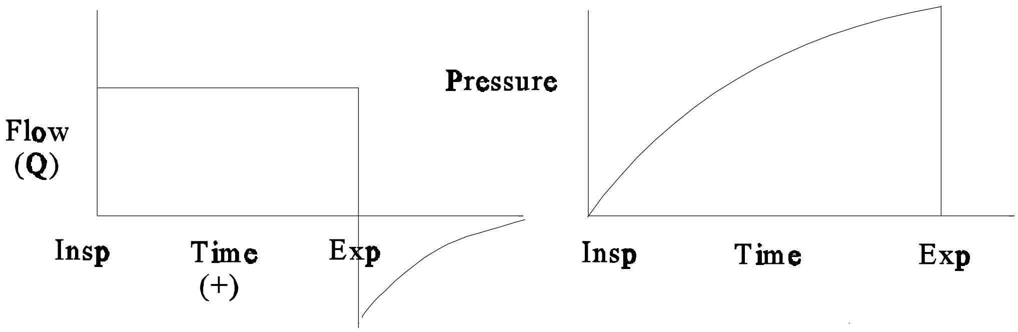
RR 30 for infants up to 1 year of age; 20 for those 1-6 years of age and 15 for those greater than 6 (which are the average normal respiratory rates for age).

I Time Based upon an I:E ratio of 1:2 for infants and pre-school age children and 1:2.5 for schoolage and adolescents. Therefore, 0.7 sec for infants up to 1 year of age; 1 sec for those to 6 years of age and 1.2 secs for those greater than 6.

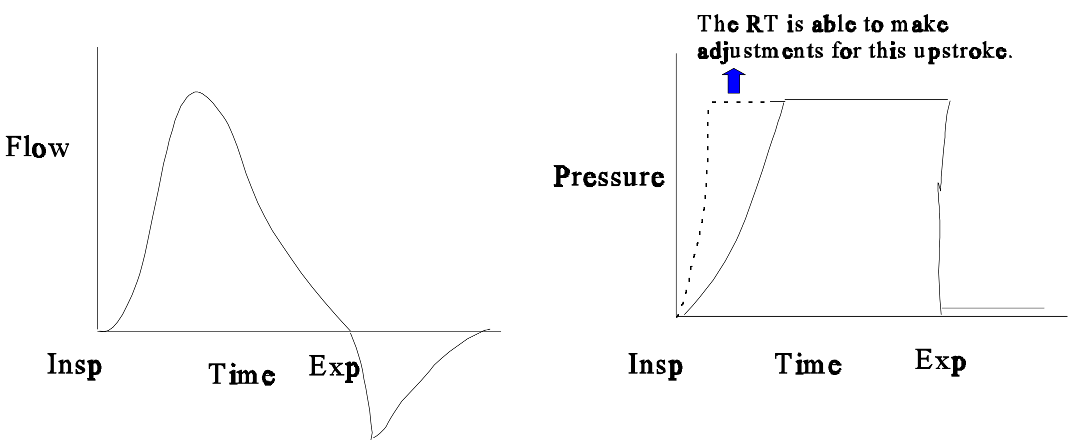
Tidal Volume 10 cc/kg (Range 8-12 cc/kg). Just a "few" years ago, many patients were started on 15 cc/kg, the volume that seemed to work "best" to prevent atelectasis in adult post-op patients ie those with normal lungs. However, with barotrauma (air leaks) and volutrauma (chronic lung disease) concerns this volume has been adjusted downwards. Think about it. It's much easier pushing 15cc/kg into normally compliant lungs than in abnormal lungs with decreased numbers of alveoli for the air to go into ie in lungs with decreased compliance. Some recent work in adults is evaluating volumes as low as 6cc/kg in association with "permissive hypercapnia." One needs to be careful, however, in using too small of a tidal volume in pediatrics. The compliance factor in the infant tubing is 0.8cc/cm H_2O ie the amount of volume that the tubing distends to or "absorbs" at a given pressure, therefore, causing a loss of volume into the lungs. If the infants PIP is 26 with a PEEP of 4, then the patient loses about 18cc (0.8 x [PIP - PEEP] or 0.8 x 22) per breath. If the child is 5kg with a dialed in volume of 50cc (10cc/kg), he may actually only be receiving 32cc or about 6cc/kg of gas into his lungs. Since the exhaled tidal volume reading is obtained at the ventilator, this lost volume into the tubing is also returned to the sensor ie it is NOT a reflection of the true volume into the lung. A dialed in volume of 60cc (12cc/kg) will ensure a volume of 8cc/kg or about a 40cc tidal volume. In an adolescent with a tubing compliance factor of 2.6cc/cmH_2O with the same PIP and PEEP, a volume of ~60cc would be lost but with a dialed in volume of 500cc (10cc/kg in a 50kg person), the resultant volume would be 440 cc or still 8.8cc/kg. (Check with your respiratory therapist whenever there is a question about the compliance factor of the tubing.)

After that being all said and done, what really determines an adequate tidal volume? All the obvious clinical parameters ie chest expansion, air entry in both bases (since positive pressure ventilation distributes gases to the apices prior to the bases) compliance expectations (the PIP at a given tidal volume, I Time, and disease state) and either end tidal pCO_2 and/or pCO_2's. What is the expected peak pressure or compliance of a normally compliant lung receiving an 8-10cc/kg tidal over a normal inspiration time and a PEEP of 3? It should be around 12-14. So, therefore, in a diseased lung with a decreased compliance, I would expect it to be at least 18-20 cm H_2O. If it's not, then I may not be giving enough volume to compensate for an inspiratory or expiratory leak. Leak will be further explained later when discussing Trigger Sensitivity. If I am still having problems with oxygenation and am already on a PEEP of 8-10, I would expect that my peak pressure would need to be at least 30cm H_2O on an SIMV Volume mode. However, if problems with oxygenation still exist and a need for a higher volume and hence PIP is considered, a switch from a SIMV Volume Control flow pattern to a SIMV Pressure Control flow should at least give a peak pressure of 26-28 over a PEEP of 10-12 if giving an adequate tidal volume to compensate for leak. Let's now look at the different modes of ventilation and why one is used over another.

The most commonly used mode is the SIMV Volume Control + Pressure Support Mode. It provides its set breaths with a constant flow and an accelerating pressure:

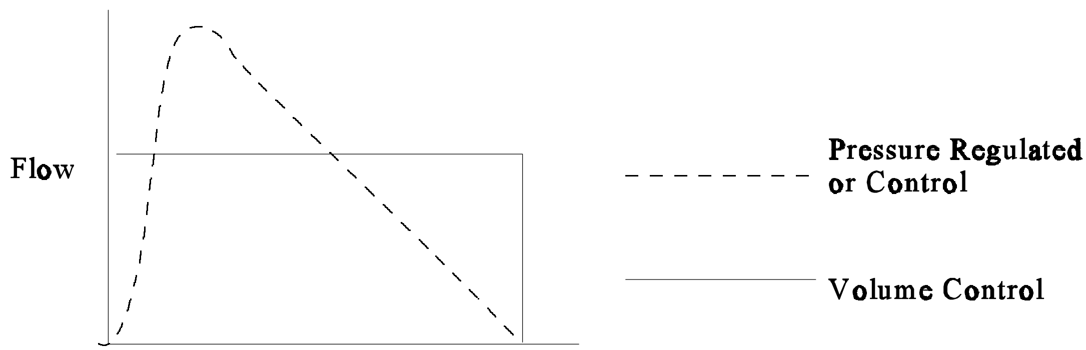


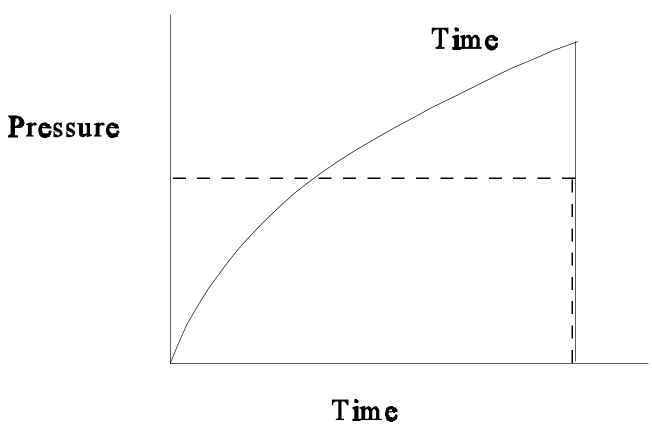
This Flow and Pressure pattern is also obtained in the pure Volume Control Mode. Its Pressure Support breaths (if Pressure Support is used) is via an accelerating/decelerating flow and a constant pressure:



This is the type of flow and pressure waves you get with any Pressure Regulated or Pressure Control mode on the 300C. It is also the Flow and Pressure Patterns of the Volume Support Mode.

The reason that the SIMV (Vol Control) mode is most commonly used is because it is the most physiologic. We normally inhale to a peak volume with a constant flow over time and a gradual peak inflation of our lungs to a peak negative inspiratory pressure. We do not maximally inflate our lungs as rapidly as seen in the accelerating-decelerating flow pattern of the Pressure Regulated or Pressure Control modes. However, the advantage of these modes lies in the ability to ventilate stiffer lungs at lower peak pressures with the same volumes. This can best be seen with the interpositioning of the flow and pressure curves of a given tidal volume over the same I time:





As you can see, the Peak Pressure is lower with the same mean airway pressure ie you should be able to provide the same degree of oxygenation at a lower peak pressure, reducing the risk of barotrauma. Therefore, if oxygenation is still a problem with high peak pressures in the SIMV Volume Control Mode, then the PRVC (Pressure Regulated Volume Control) becomes usually the next mode chosen. However, this is a control mode. If the machine has a breath "triggered" then the full dialed in Volume and I Time is delivered. In this mode you still use the same settings as in the SIMV Volume Control Mode ie Tidal Volume, Rate, I-Time, PEEP, FiO_2 except you don't need to worry about Pressure Support.

Let's now discuss what "triggers" a breath before we go further since this issue may help determine what mode is chosen ie a mode other than SIMV Volume Ventilation or Pressure Regulated Volume Controlled Ventilation.

(Knob) Trig. Sensitivity Level below PEEP

The trigger can be set to either flow trigger or pressure trigger. Any setting (ie in the green/red area) below O (zero) will place the machine in the flow triggering mode. The trigger is based upon changes in a continuous expiratory flow in the circuit. An inspiratory effort will decrease the flow and a breath will be triggered. However, other mechanical factors such as secretions, water in the tubing, tube position, leak around the tube, may all cause a sensed decrease in expiratory flow required to maintain a set PEEP and hence a breath will be triggered. This breath may be a full or a supported breath depending upon the mode. Air may become trapped or the patient may become over ventilated without you being aware of this. Many times you will actually hear "self-cycling" occurring. At other times, you may just have a lower pCO_2 than expected. Whenever a breath is thought by the machine to be triggered, the yellow light on the bottom of the pressure column comes on. This light should be in synch with the patient's own respiratory efforts. You can ensure yourself of this by either seeing or feeling the patient's efforts coincide with the light coming on.

At trigger sensitivities set at O (zero) or above, ie pressure triggering, the patient must inhale the whole continuous expiratory flow and also create a pressure below PEEP to trigger a breath. This may be required when a significant leak causes this loss of expiratory flow in order to prevent "self-cycling." Working in concert with the Respiratory Therapist will determine the best "Trigger Sensitivity Level" or whether or not a new mode is required.

The next modes that come immediately to mind are the Pressure Control Mode of the SIMV (Pressure Control) + Pressure Support Mode. Instead of setting a volume, you set a "Pressure Above PEEP." The breaths are delivered with an accelerating-decelerating flow pattern and a "constant" pressure (ie "square wave"). These modes are normally used when a leak of volume occurs. Leak normally occurs mainly on expiration. However, when a leak of volume occurs on inspiration and hence a volume loss into the lungs then use of a pressure mode is warranted. The machine adjusts the flow and inspiratory volume to maintain a set pressure. This is OK if compliance remains fairly constant. HOWEVER, with changing compliance, volumes may change if the pressure is not adjusted. Again, work closely with the Respiratory Therapists on these issues. The difference between the inhaled and exhaled tidal volume readings allows you to maintain a sense of leak. It doesn't , however, tell you where this leak occurs, ie inspiration or expiration. The hearing and feeling at air lost on inspiration may help determine this. So don't be overly concerned if in a Pressure Control Mode (SIMV or Pressure Control itself) if you set a pressure of 20 above PEEP on a 5kg infant and see an inhaled tidal volume of 200cc and an exhaled tidal volume of 10cc. As long as the chest is moving and you are hearing adequate air exchange and the other parameters of ventilation are met, then you are OK. Patients (or for that matter, yourself) would not like gauze or other items shoved in the back of their (your) throat just to make numbers improve ie more use of sedation +/or paralysis may be required. There are, however, rare circumstances where this may be required. Discussion with the RT's, nurses and PICU attending "might" help in this decision.

Another mode is a fairly self explanatory mode ie "CPAP + Pressure Support." The patient initiates all pressure supported breaths. “Self cycling” may occur. These pressure supported breaths are like all other pressure breaths, a constant pressure with an accelerating-decelerating flow pattern.

The last mode to discuss is becoming a favorite of mine. If ever I would require ventilation, (for only a “short” period), then I would want to be ventilated in the “Volume Support Mode”. I would be able to determine my rate, my I-Time at a set Tidal Volume with the Peak Pressure changing as my lung’s compliance changes. My Peak Pressure would be minimized since the flow is an accelerating -decelerating flow pattern at a constant pressure that changes. If I would become apneic, then the machine automatically would switch to a back-up setting in the PRVC (Pressure Regulated-Volume Control) Mode.

What determines the length of the I-Time ie what cycles the supported breaths into expiration is a bit confusing. There are at least three different mechanisms and there may be others that only the RT’s are aware of. What I pay attention to most is that the patient needs to have a normal respiratory pattern ie a normal inspiration and expiration. If inspiration or expiration seems too long or too short, then I look for problems with either the triggering mechanism or a problem with the machine cycling into expiration. The two most common ways of cycling into expiration are 1) when the inspiratory flow reaches 5% of peak flow ie at the end of inspiration, there is less of a flow requirement to meet the patient’s needs ie less than 5% of peak which allows expiration to occur. The other limit is a time limit. The inspiratory time cannot exceed 80% of the dialed in cycle time calculated from the “CMV frequency, breath per minute” knob (not necessarily the SIMV rate in an SIMV mode) ie if the knob is set at 40, then the cycle time is 1.5 seconds ie the time for both inspiration and expiration to occur. 80% of 1.5 secs is 1.2 secs ie the inspiratory time of a supported breath either in pressure support or volume support cannot exceed 1.2 secs.

For other questions about the use of the Siemans 300, please consult your “friendly” Respiratory Therapist or the PICU attending.