Initial Mechanical Ventilation

Types of Ventilators used in the Twin Cities for pediatric patients.

	Types of ventilation	Modes
Sechrist	pressure	Pressure Control/IMV/CPAP
Servo 900	volume and pressure	PC/VC/SIMV/SIMVcPS/PS
Servo 300	volume and pressure	Numerous
VIP Bird	volume and pressure	Numerous
Drager	volume and pressure	Numerous
Infant Star	pressure	SIMV and Assist Control
LP-10	volume and pressure	SIMV and Assist Control

(The LP-10 is a portable vent used primarily for home/ambulatory ventilation)

HCMC, the U and CHC-St. Paul all have the Servo 900C, the U also has the Servo 300, Sechrists, Infant Stars and the Drager are in the NICU on F4. CHC-St. Paul uses the VIP Bird frequently, as does CHC-Mpls. HCMC also uses Adult Star ventilators for the bigger kids and Bear Cub's for the neonates.

Blood Gases

The most simple way to look at mechanical ventilation is as a way to keep the blood gases normal. So what makes up a Blood Gas?

pH hydrogen Ion concentration
pCO_2 partial pressure of Carbon dioxide

pO_2 partial pressure of oxygen

You get several other values, but many of these are calculated and/or not reflective of pulmonary function which is what you are controlling with MV.

pH and pCO_2 are closely related and are affected by ***minute ventilation***.

pO_2 is governed by ***oxygen delivery*** and ventilation and perfusion (***V*** and ***Q***) ***match***.

Minute Ventilation - very simply is RRxTV, respiratory rate times tidal volume.
Because CO_2 rapidly diffuses across the alveolar space the more air you can move into and out of the lungs the more rapidly the CO_2 can be removed.

Oxygen Delivery and VQ match - is controlled by your FiO_2 (fraction of inspired oxygen) and is related to your airway recruitment. Airway recruitment is indirectly reflected in your *mean airway pressure (MAP)*. By increasing your mean airway pressure you can increase your airway recruitment (although this is not a linear relationship) MAP is a function of the PEEP (positive end expiratory pressure) and a fraction of the PIP (peak inspiratory pressure or Pmax).

Quick review
So, to control pH and pCO_2, you manipulate the minute ventilation, ergo the respiratory rate and tidal volume.
To control pO_2, you manipulate the oxygen delivery and the VQ match, ergo you adjust the FiO_2 and the mean airway pressure (PEEP and PIP)

Basic Ventilator Types:

Volume Control	**Pressure Control**
Controls	
Rate	Rate
PEEP	PEEP
FiO_2	FiO_2
Tidal Volume	Peak Inspiratory Pressure
Inspiratory Time	Inspiratory Time
Relative Advantages/Disadvantages	
Known TV	No guarantee of TV
Risk for barotrauma	**pressure limited**
	decreases risk of barotrauma
Uses	
Most ventilated patients	neonates
Patients in OR (including neonates)	patients where pressure is a concern
	ARDS, asthmatics sometimes

Another Quick Review

Volume Control Ventilation

Controlling pH and pCO_2 is done by controlling minute ventilation. You can set both the respiratory rate and the tidal volume.

Controlling pO_2 you can adjust the FiO_2, the PEEP and, indirectly, the PIP by adjusting the tidal volume (bigger TV yields bigger Pmax) although we don't do this so much in practice

Pressure Control Ventilation

Controlling the pH and pCO_2 is done by controlling the minute ventilation. You can set the RR, but the TV is managed indirectly. TV is directly proportional to your ΔP (PIP-PEEP). Over a pressure range this will vary, the higher the pressures the less TV for a given ΔP.

Controlling the pO2, again you can adjust the FiO2 and the PEEP, in addition you control the PIP (again we rarely use this clinically)

Now you know the basics of mechanical ventilation. So we can move on.

Modes

The ventilator mode determines both when a patient gets a breath and what kind of breath they receive. The goal is to select a mode that is both comfortable for the patient and allows adequate ventilation and oxygenation with minimal trauma. Here is a partial list of available modes, with a brief discussion. Unless otherwise mentioned these modes are all in volume control, meaning that you set the tidal volume, rather than the peak inspiratory pressure. Some newer ventilators, particularly the Servo 300 can do these modes in either pressure or volume control.

IMV (Intermittent Mandatory Ventilation)

Characteristics: set breath delivered at a fixed interval. No patient interaction, pressure or volume modes

Uses: commonly in neonates on the Sechrist, can be a weaning mode

Contraindications: none really, unfriendly to older patients

Advantages: regular guaranteed breath

Disadvantages: does not allow patient to breath with the ventilator except by chance. Does not work with the patient

Ventilators: Sechrist, most others can do this as well.

SIMV (Synchronous IMV)

Characteristics: set breath delivered within an interval based on the set respiratory rate. Ventilator spends part of the interval waiting for spontaneous breath from the patient, which it will use as a trigger to deliver a full breath. If not sensed it will automatically give a breath at the end of the period. Any other breaths during the cycle are not supplemented.

Uses: commonly used in many settings. Can be a weaning mode (see also with PS)

Contraindications: none in particular

Advantages: allows work with the patient, somewhat more friendly.

Disadvantages: Any other breaths during the cycle are not supplemented

Ventilators: all but the Sechrist

PS (Pressure Support)

Characteristics: supports each spontaneous breath with supplemental flow to achieve a preset pressure. Gives a little push to get the air in, so to speak.

Uses: In the spontaneously breathing patient this helps overcome the airway resistance of the endotracheal tube. Usually use 5 for older patients and 10 for smaller (smaller ETT has higher resistance, more impediment to flow). Can be very helpful for weaning.

Contraindications: patient who is not spontaneously breathing, i.e. on muscle relaxants

Advantages: helps overcome resistance of tube, making spontaneous breathing easier

Disadvantages: the flow rate is very high on the Servo 900C, which can make pressure support uncomfortable for some small patients. This is hard to predict.

Ventilators: All but Sechrist

SIMV/PS

Characteristics: combination of the previous two modes. Extra breaths in the cycle are supplemented with pressure support.

Uses: useful in most circumstances, including weaning.

Contraindications: none in particular.

Advantages: allows both synchrony with the patient and help in overcoming the resistance in the endotracheal tube, to allow easier spontaneous breathing.

Disadvantages: none in particular. PS does not add anything in the patient who is not spontaneously breathing. Sometimes patients will have difficulty with the pressure support on some ventilators.

Ventilators: all but the Sechrist

AC (assist control) or *VC* (Volume Control)

Characteristics: preset rate and tidal volume (sometimes PIP), either on the patient's initiative or at the set interval a full mechanical breath is delivered.

Uses: for patients who have a very weak respiratory effort, allows synchrony with the patient but maximal support. Not a weaning mode, as at any rate they are getting complete mechanical support.

Contraindications: none in particular

Advantages: a fairly comfortable mode, providing a lot of support

Disadvantages: can lead to hyperventilation if not closely monitored, not able to wean in this mode.

Ventilators: LP-10 (a portable ventilator), Servo 900, Infant Star

PC (Pressure Control)

Characteristics: basically IMV, where the breath is controlled by the Pmax or Swing pressure and not the set tidal volume

Uses: in neonates, or in patients with high airway pressures(such as ARDS) to avoid barotrauma

Contraindications: none in particular, not a friendly mode in an awake patient

Advantages: Pressure limited, decreases the risk of barotrauma

Disadvantages: no guaranteed tidal volume

Ventilators: all.

PRVC (Pressure Regulated Volume Control)

Characteristics: a volume control IMV/SIMV, that adjusts the flow rate of the delivered air to deliver the set tidal volume at or below the set maximum pressure.
Uses: in patients with high airway pressures
Contraindications: none in particular
Advantages: gives you a guaranteed tidal volume but minimizes barotrauma.
Disadvantages: new, no particular disadvantages.
Ventilators: only available on the Servo 300

CPAP (Continuous Positive Airway Pressure)

Characteristics: just as it says. This is the same as PEEP.
Uses: for patients with upper airway soft tissue obstruction or tendency for airway collapse. As a final mode prior to extubation in some patients.
Contraindications: any patient without spontaneous respiratory effort. Not a good idea in a patient with obstructive pulmonary disease (like asthma, COPD)
Advantages: simple, easy to use
Disadvantages: provides no supportive ventilation.
Ventilators: all.

Where to start?

Every patient is different and it is hard to know exactly what a patient will need in terms of ventilatory support until they are actually on the ventilator. So many of us a have preset ideas as to where to start any patient and then adjust the ventilator afterwards to achieve the desired ventilation effect.

Pressure vs. Volume: Choose **Volume** to start.

Why? generally a more friendly method, more to choose from, also you have the benefit of the guaranteed tidal volume which is important, especially early

Mode: **SIMV** with or without **Pressure Support**.

Why? again a patient friendly mode. Pressure support is only helpful if the patient is going to be spontaneously breathing. Would use PS of 5 in big patient, 10 in small.

Rate: **20**

Why? A good place to start. You can always adjust later. For small children this is lower that their usual spontaneous rate but with the larger tidal volumes that are delivered this increases the minute ventilation.

Peep: **5mm Hg**

Why? a little above physiologic. Not so high as to cause problems.

FiO_2: **100%**

Why? You can start to wean once you are certain everything is stable. Allows maximal preoxygenation in case anything happens.

Tidal Volume: **10ml/kg**

Why? Above physiologic, gives good distention without significant barotrauma. 10-12ml/kg is the standard range.

Inspiratory Time: somewhere from **0.5 to 1** second

Why? physiologic. Longer for bigger kids. But this will vary on the situation. Asthmatics for example merit very short I-times to allow maximal time for exhalation.

Early things to worry about

Peak Pressures: You would like to keep these under 40 if at all possible. If they start climbing into the higher 40's to 50's you should consider changing to Pressure control ventilation.

Oxygenation: Inability to wean the FiO_2 should be a concern. Once on the ventilator the goal should be to get the FiO_2 under 60%. If you are unable to do this it implies shunting either from lack of airway recruitment (PEEP too low) or alveolar inflammation or disease (like ARDS). This is where increasing the Mean Airway Pressure will be of benefit.

Ventilation: Am I over or under ventilating this patient based on his needs. Remember a patient who is being intubated because of an upper airway problem may have an excellent respiratory drive and not need much support. While a patient in shock with profound metabolic acidosis may need a higher rate to help compensate. Keep in mind the reason you are putting the patient on the ventilator. Obtaining a blood gas early after intubation (15-20 minutes after being on the ventilator) will help you decide if you are moving in the right direction.