Recent Advances in Mechanical Ventilation for Anesthesiologist

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Advances in mechanical ventilation

1. Pressure regulated volume control
2. Volume support ventilation
3. Airway Pressure release ventilation
4. Adaptive support ventilation
5. Neurally adjusted Ventilatory support
6. Mandatory Minute ventilation
7. Proportional assist ventilation
8. Knowledge based system
Auto-Flow or Pressure Regulated Volume Control (PRVC) Mode
Volume control ventilation + Pressure control ventilation

Auto Flow Dräger (Anesthesia/ICU)
Pressure Regulated Volume Control (PRVC) : Maquet (ICU)
Pressure Control Mode vs Auto-flow

- **PCV:** With change in lung mechanics VT delivery is not guaranteed (airway obstruction, change in posture etc)
- **Auto-Flow:** PC breaths with **target tidal volume**
- Inspiratory pressure adjusted to deliver VT
- Like PCV – constant airway pressure, variable flow (flow as demanded by patient)
How does Auto-Flow work?

- **First breath is a volume control breath**
- The inspiratory pressure for the next breath is based on the plateau pressure of the first breath
- Then up to +/- 3 cm H2O changes per breath
- If the VT increases, the pressure support decreases by up to 3 cm H2O until the desired VT is reached

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Auto Flow: Advantages

- Pressure adjusted for changes in compliance and resistance
- Maintains a minimum PIP
- Guaranteed $V_T$ and $V_E$
- Allows patient control of respiratory rate and $V_E$
- Breath by breath analysis
- Limits volutrauma
- Prevents hypoventilation
Auto-flow (Dräger evita 4, XL)

Volume control SIMV/AF/PS/Sync ON
Auto Mode (PRVC): Indications

- Can be used routinely to take advantage of two modes in one (volume and pressure)
- Patient who require the lowest possible pressure and a guaranteed consistent $V_T$
- ALI/ARDS
- Patients requiring high and/or variable MV
PRVC: Disadvantages

- Pressure delivery is based on previous $V_T$ and varies
- Intermittent patient effort $\Rightarrow$ variable $V_T$
- Varying mean airway pressure
- Leaks are not compensated
- A sudden increase in respiratory rate and demand may result in a decrease in ventilator support
Pressure Controlled Ventilation

Pressure Controlled Inverse Ratio ventilation (PC-IRV)

Airway Pressure Release Ventilation
Airway Pressure release ventilation (APRV)

- I:E ratio is 4-5:1
- Spontaneous breath are not supported
- At times requires paralysis

Pressure Control Inverse ratio Ventilation (PC-IRV)

- I:E ratio can be even 5-15:1
- Spontaneous breath are fully supported
- No paralysis required
- Maintains MAP
Airway Pressure Release ventilation (APRV)

- Provides 2 levels of CPAP and allows spontaneous breathing at both levels
- CPAP released periodically for a brief period.
- Short release with spontaneous breathing promote CO$_2$ elimination
- Auto-PEEP is a possibility
**APRV: Terminology**

- **P\(_{\text{high}}\)**: Inspiratory pressure + Plow pressure (peak pressure)
- **P\(_{\text{low}}\)**: Expiratory pressure (PEEP)
- **T\(_{\text{high}}\)**: Time spent during inspiration (Insp time)
- **T\(_{\text{low}}\)**: Time during deflation (Exp time)

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- do not let expiratory flow returning to zero
- Set Plow (PEEP) at 0 cm H₂O.
- Set T low so that expiratory flow from patient ends at about 50 to 75% of peak expiratory flow
- Avoid lung collapse during T_{low}. 

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Advantages

- **Higher pressure:** Alveolar recruitment, better oxygenation, maintenance of mean alveolar pressure
- **Lower pressure:** alveolar ventilation and CO₂ removal
- **Recruitment of diseased lung**
- **Allows spontaneous breathing and hence better gas distribution to the dependent lung regions**
- **Decreased work of breathing**
- **Constant recruitment including slow opening alveoli:** Improved V/Q matching
Airway Pressure Release Ventilation (APRV)

- Disadvantages
  - Volume changes with alteration in lung compliance and resistance
  - Could be harmful to patients with high expiratory resistance (i.e., COPD or asthma)
  - Caution: in hemodynamically unstable patients
    Increase RV strain and after load, and PHT
  - Spontaneous breath during $T_{\text{low}}$: Increase WOB
  - Worsening of air-leak (BPF)
  - Auto-PEEP is usually present
Airway Pressure Release Ventilation (APRV)

- **Indication**
  - ARDS
  - Hypoxemia
  - Atelectasis
  - Need for higher PEEP

- **Settings**
  - $P_{\text{high}}$: plateau pressure of conventional ventilation
    - Use previous mean alveolar pressure/plateau pressure
  - $T_{\text{high}}$: Inspiratory time (5.5-6.5 sec)
  - $P_{\text{low}}$: 0 cm H$_2$O (PEEP) (intentional auto-PEEP)
  - $T_{\text{Low}}$: 0.4-0.6 sec
    - $T_{\text{Low}}$ should be equal to 40%-50% of peak expiratory flow
Spontaneous Breathing

Spontaneous Breaths (On P High)

Patient Trigger (On P High)

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Airway Pressure Release Ventilation (APRV)

- **Hypoxia**
  - Prolong $T_{\text{high}}$ by 0.5 to 1 sec
  - Increase $p_{\text{High}}$ by 2-5 cm H$_2$O

- **Hypercapnia**
  - Tolerate permissive hypercapnia
  - Decrease $T_{\text{high}}$ by 0.5-1 sec
  - Shorter $T_{\text{High}}$ means more release/min.

**Example:**
- $T_{\text{High}}$ 5 sec. = 12 releases/min
- $T_{\text{High}}$ 4 sec = 15 releases/min
APRV: Weaning

1. Decrease FIO$_2$
2. Reduce P$_{\text{High}}$, by 2 cmH$_2$O
3. Increase T$_{\text{High}}$
4. P$_{\text{high}}$ 15 cm H$_2$O and T$_{\text{high}}$ 15 sec - CPAP
Pressure Support

Volume Support

SIMV
Volume support (Servo)

- All breaths are patient triggered, pressure limited, and flow-cycled.
- In this mode the pressure is automatically adjusted by the ventilator to meet the minimal set tidal volume.
- Pressure support changes with each breath, depending on the patients activity to achieve the target VT.
- Patient controls the I:E and the total inspiratory time
- This improves the ventilator-patient synchrony.
Volume support (Servo)

- As the patient breaths deeper, the ventilator gives less pressure.
- If the patient generates little pressure, the ventilator gives more support.
- Back up (if rate is too low or apnea) is PRVC or VC.
- Allows the respiratory muscles to take on work of breathing.
1. VS test breath (5 cm H2O)
2. pressure is increased slowly until target volume is achieved
3. maximum available pressure is 5 cm H2O below upper pressure
4. VT higher than set VT delivered results in lower pressure
5. patient can trigger breath
6. Apnea: Ventilator switches to PRVC (auto-mode)
Volume support (VS)

Advantages

- Guaranteed VT and VE
- PS breaths using the lowest required pressure
- Patient’s spontaneous respiratory rate
- Patient WOB
- Allows patient control of I:E time
- Breath by breath analysis
- Variable inspiratory flow to meet the demand
Volume support (VS)

Disadvantages

- Spontaneous ventilation required
- $V_T$ selected may be too large or small for patient
- Varying mean airway pressure
- Auto-PEEP may affect proper functioning
- A sudden increase in respiratory rate and demand may result in a decrease in ventilator support
Volume Support (VS)

Indications

- Spontaneous breathing patient who require minimum $V_E$
- Patients who have inspiratory effort who need adaptive support
- Patients who are asynchronous with the ventilator
- Used for patient who are ready to wean

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Neurally adjusted Ventilatory support

Steps necessary to transform central respiratory drive into an inspiration at which technology able to control a ventilator could be implemented.

Central nervous system → Phrenic nerve → Diaphragm excitation → Diaphragm contraction → Chest wall and lung expansion → Airway pressure, flow and volume

Ideal technology → Neural (NAVA) technology → Ventilator unit

Current technology
Neurally adjusted ventilatory assist (NAVA)

- **Normal**: Initiation of inspiration: flow or pressure but there could be delay in providing the support

**NAVA**:

- Triggering achieved through electrical activity of the diaphragm (EAdi)
- **Ventilator delivers an inspiratory pressure proportional** to the electrical activity of the diaphragm (EAdi)
- EAdi includes both frequency and intensity
- Recording done by esophageal catheter
- Patient controls inspiratory time
- **No signal**: PS ventilation and apnea PC mode

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Neurally adjusted ventilatory mode
Neurally adjusted ventilatory assistance

EMG tracings: 4, obtained from 8 differential electrodes electrical activity of the diaphragm (EAdi)
EMG signal from the closest pair to the diaphragm, is transformed into a waveform
### NAVA: ventilator setting

<table>
<thead>
<tr>
<th>Inspiratory PS</th>
<th>VT 6–8 ml/kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flow-trigger</td>
<td>lowest possible</td>
</tr>
<tr>
<td>Expiratory trigger</td>
<td>30% of the peak inspiratory flow</td>
</tr>
<tr>
<td>Level of assistance</td>
<td>PSV-100 and ↑ or ↓</td>
</tr>
</tbody>
</table>

#### Too low NAVA level:
- rapid shallow breathing and Neural output shows high EAdi signal
- Increase NAVA support EAdi signal decrease until plateau and patient is comfortable

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