Mechanical Ventilation: Schedule

- History, Concepts and Basic Physiology – Nader
- Volume Control Ventilation (CMV, ACV) – Nader
- Intermittent Mandatory Ventilation (SIMV) – Nader
- Pressure Support Ventilation (PSV) – Nader
- Pressure Control Ventilation (PCV) – Junker
- Pressure Regulated Volume Control (PRVC) – Junker
- Airway Pressure Release Ventilation (APRV) – Junker
- Neurally Adjusted Ventilatory Assist (NAVA) – Nader
If you take a dead animal and blow air through its larynx, you will fill its bronchi and watch its lungs attain the greatest distention.
The Drager Pulmotor

1911 “Artificial Breathing Device”
The Drager Pulmotor… *used by Fire and Police Units*
1900-1950

Iron Lung
1927

Philip Drinker
Rancho Los Amigos Hospital, 1953
Era of Respiratory Intensive Care

1950-1970

- Bird Mark 7
- Bennet PR2
- Hamilton Standard
- Bear
Role of Mechanical Ventilation:

- Provide oxygenation and ventilatory support during respiratory failure
- Improve gas exchange
- Unload respiratory muscles
- "Buy time" for healing and recovery
Controlled MV
Control/Assist
Assist
Combined
Complex Algorithms

1950

SIMV

Pressure Support
Volume Support

APRV, BiPAP, Automode

PEEP

2011

NAVA
PAV
ASV
Other
Mechanical Ventilation:

Positive Pressure
- Invasive
  - CMV, AC
  - SIMV
  - PS / PC
  - APRV / Bi-level
- Non-Invasive
  - BiPAP
  - CPAP
  - PAV, ASV, NAVA

Negative Pressure
- The Iron Lung
A Double-Edged Sword

Mechanical Ventilation

Biochemical Injury
- cytokines, complement, prostanoids, leukotrienes, reactive oxygen species, proteases
- bacteria

Biophysical Injury
- shear
- overdistention
- cyclic stretch
- intrathoracic pressure ↑

Distal Organs
- tissue injury secondary to inflammatory mediators/cells
- impaired oxygen delivery
- bacteremia

MSOF
- Hypotension post induction
- Hypertension due to agitation, pain, stimulation
- Hypercapnea $\rightarrow$ cerebral vasodilation
- Hypoxemia, Acidosis, PEEP
CNS
→ Phrenic nerve
→ Diaphragm excitation
→ Diaphragm contraction
→ Chest wall, lung and esophageal response
→ flow, pressure, volume changes

Ideal Technology

Ventilator

Current Technology
Breath characteristics

**Trigger**: what initiates a breath
- **Timer** (control) vs **Effort** (assist)

**Gas delivery target**: what governs gas flow
- Set **flow** vs Set **insp pressure**

**Cycle**: what terminates the breath
- **Volume**, **Time**, **Flow**, **Pressure**

*MacIntyre, principles of mechanical ventilation, 2008*
A ventilator breath that is *patient triggered*, *pressure targeted*, and *time cycled* is termed:

A) Volume Assist  
B) Pressure Support  
C) Pressure Control  
D) Pressure Assist
A ventilator breath that is patient triggered, pressure targeted, and time cycled is termed:

A) Volume Assist  
B) Pressure Support  
C) Pressure Control  
D) Pressure Assist
A ventilator breath that is patient triggered, pressure targeted, and time cycled is termed:

A) Volume Assist (flow targeted, volume cycled)
B) Pressure Support (flow Cycled)
C) Pressure Control (machine triggered)
D) Pressure Assist (Pressure “Assist” Control)
<table>
<thead>
<tr>
<th>Breath characteristic</th>
<th>Trigger</th>
<th>Target / Limit</th>
<th>Cycle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume Control (VC)</td>
<td>Time</td>
<td>Flow</td>
<td>Volume</td>
</tr>
<tr>
<td>Volume Assist (VA)</td>
<td>Effort</td>
<td>Flow</td>
<td>Volume</td>
</tr>
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<td>Pressure Control (PC)</td>
<td>Time</td>
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<td>Pressure Assist (PA)</td>
<td>Effort</td>
<td>Pressure</td>
<td>Time</td>
</tr>
<tr>
<td>Pressure Support (PS)</td>
<td>Effort</td>
<td>Pressure</td>
<td>Flow</td>
</tr>
<tr>
<td>Pressure Release (PR)</td>
<td>Time</td>
<td>Pressure</td>
<td>Time</td>
</tr>
<tr>
<td>Spontaneous (SP)</td>
<td>Effort</td>
<td>Pressure</td>
<td>Effort</td>
</tr>
</tbody>
</table>
Trigger

- Level of effort needed to start a ventilator breath

  - **Pressure trigger** - effort produces pressure drop in vent circuit

  - **Flow trigger** - effort draws gas out of a continuous flow through the vent circuit

*MacIntyre, principles of mechanical ventilation, 2008*
**Trigger - Pressure**

a) Effort
   - *Short Delay*

b) Pressure drop sensed as effort
   - *Short Delay*

c) Flow initiation by ventilator

d) Target reached

*MacIntyre, principles of mechanical ventilation, 2008*
Pressure Trigger:

Sensitivity determined by a set pressure drop

- *Too sensitive*..
  - Interference by motion, external stimulation, suctioning, air leaks in circuit or chest tubes, etc..

- *Too high*..
  - Increased work of breathing
  - Dyssynchrony, discomfort
Flow Trigger:

- When the difference between insp and exp flow equals the preset flow trigger → New Inspiration
- Less delay in Response Time
- Decreased work of breathing
Flow Triggered
MacIntyre, Principles of Mechanical Ventilation, 2008

Gas Delivery

Pressure is “dependant variable” – varies based on lung mechanics

Airway Pressure

Set flow

Flow

in

out

Either Set $t_i$ or Set minimal flow (cycle off)

Volume

Set volume (cycle off)

Increasing

0 2 4 6 8 10 12 14 16

Volume t Pressure
Flow and Volume are dependant variables
Cycle …*what terminates the breath*

Cycling occurs in response to:

- Delivered *Volume*
- Elapsed *Time*
- Predetermined decrement in *Flow Rate*

After cycling occurs, exhalation valves open, inspiration ends, and passive exhalation occurs

*MacIntyre, principles of mechanical ventilation, 2008*
Inspiratory rise time:

- Time taken to reach inspiratory flow or pressure at the start of each breath
- % of cycle time in controlled modes
- Time (seconds) in PS/CPAP, or VS
**Inspiratory cycle off:**

- Point at which inspiration changes to expiration

(Spontaneous and Supported modes)
Time Constant Valve Controller
**PEEP:** Positive End Expiratory Pressure

- 0 – 50 cmH2O (usually <12)
- Pressure to prevent collapse of the alveoli, small airways, and maintain FRC
ALI / ARDS
No Flow: \( P_{AW} = P_{Alveoli} \)
Under “No Flow” conditions (static)

- Only distending pressure in Alveoli measured
- End-Inspiratory Pressure = $P_A = P_{\text{plateau}}$
- End-Expiratory Pressure = $P_A = \text{PEEP}_i$

During “Flow Conditions”, airway pressures are affected by both distending pressures as well as flow-related pressures.
- Insp flow = 1 L/sec
- Exp flow (peak) = 2 L/sec
- $V_T = 1$ Liter
- $P_{\text{peak}} = 40$ cm H$_2$O
- $P_{\text{plateau}} = 30$ cm H$_2$O
- Base $P_{\text{(PEEP)}} = 0$ cm H$_2$O
- Peak $P_{\text{es}} = 10$ cm H$_2$O
- Base $P_{\text{es}} = 0$ cm H$_2$O

MacIntyre, principles of mechanical ventilation, 2008
Flow Pressures:

\[ P_{\text{peak}} - P_{\text{plateau}} = \text{Pressure for Flow} \]

\[ 40 - 30 = 10 \text{ cm H}_2\text{O} \]

Distending Pressures:

\[ P_{\text{plateau}} - P_{\text{base(PEEP)}} = \text{Pressure to distend resp system (lung+cw)} \]

\[ 30 - 0 = 30 \]

\[ \text{Peak } P_{\text{es}} - \text{Base } P_{\text{es}} = \text{Pressure to distend chest wall (P}_{\text{CW}}) \]

\[ 10 - 0 = 10 \]

\[ P_{\text{Resp system}} - P_{\text{Chest wall}} = \text{Pressure to distend lungs} = 20 \]

MacIntyre, principles of mechanical ventilation, 2008
Compliance

- The inverse of lung elastance

- The pressure required to expand the lung and change the lung volume
  \[ C = \frac{V}{P} \]

- \( C_{\text{static}} \) - no air movement

- \( C_{\text{dynamic}} \) - during active inspiration
Compliance

\[ C_{rs} = \frac{V_T}{(P_{plateau} - PEEP)} \]
\[ = \frac{1}{(30-0)} = 0.0333 \text{ L/cm H2O} \]

\[ C_{cw} = \frac{V_T}{\text{Peak } Pes - \text{Base } Pes} \]
\[ = \frac{1}{(10-0)} = 0.100 \text{ L/cm H2O} \]

\[ C_L = \frac{V_T}{C_{rs} - C_{cw}} \]
\[ C_L = \frac{V_T}{(P_{plateau} - PEEP - \text{Peak } Pes - \text{Base } Pes)} \]
\[ = \frac{1}{(30-0-10-0)} = 0.05 \text{ L/cm H2O} = 50 \text{ ml/cm H2O} \]
**Resistance and Compliance**

**Transairway Pressure (P_{TA})**

The pressure required to overcome $R_{AW}$ as gas flows through the airways.

\[ P_{TA} = \text{flow rate} \times R_{AW} \]

**Alveolar Pressure (P_{A})**:

Pressure required to deliver a tidal volume against the recoil force of the alveoli

The effect of increased airways resistance on the pressure waveform

\[ P_A = P_{\text{plateau}} = P_{\text{static}} \]

\[ P_{\text{PIP}} = P_{TA} + P_{\text{plateau}} \]
Resistance and Compliance

As lung compliance decreases the **static or plateau pressure** increases resulting in increased peak pressure

Example:

\[ V_T = 750 \text{ mL} \]
\[ \text{Flow} = 5 \text{ cm H}_2\text{O} \]
\[ C_{RS} = 50 \text{ mL/cm H}_2\text{O} \]
\[ P_{\text{plateau}} = 15 \text{ cm H}_2\text{O} \]
\[ P_{\text{TA}} = \text{flow} \times R_{\text{AW}} \]
\[ \text{PIP} = P_{\text{TA}} + P_{\text{plateau}} \]
Flow Pattern: Volume Control Ventilation

Maquet Pocket Guide, Modes of Ventilation, Servo-I
Flow Pattern: Pressure Control Ventilation

Examples: PC, PRVC, PS, VS, SIMV (PRVC, PC) + PS
Effect of changing Respiratory Frequency (f) on Cycle Time ($T_c$)

(A) RR increased to 20, cycle time decreases to 3 sec and expiratory time decreases to 1.5 sec

(B) RR decreased to 12, cycle time increases to 5 sec, since the inspiratory time remains unchanged, expiratory time increases to 3.5 sec
Effect of changing Inspiratory Flow Rate on Inspiratory and Expiratory times

(A) Increased Inspiratory Flow → Decreases insp time → Longer expiration time

(B) Decreased Inspiratory Flow → increases insp time → decreases exp time
Modes of Ventilation

Selection of ventilator mode depends on:

- Clinical setting and patient pathophysiology
- Institutional guidelines and clinician preferences
Volume Control

Variable Pressure

Constant Flow

Preset Tidal Volume
Controlled Mechanical Ventilation

Volume Targeted

Pressure Targeted

Minute ventilation is **completely** dependent upon the respiratory rate and tidal volume set.
Volume Control: Assist Control

![Graphs showing flow, pressure, and volume over time.](image)
Volume Control: Flow Adapted
Volume Control: Assist Control

- **Advantages:**
  - Reduced work of breathing
  - Guarantees delivery of set tidal volume and minute ventilation

- **Disadvantages:**
  - Potential adverse hemodynamic effects
  - May lead to inappropriate hyperventilation and excessive inspiratory pressures
  - Cannot ventilate effectively and consistently unless the airway is well sealed
Volume or Pressure

- **Volume Assist:**
  - $T_v$ guaranteed, less worry about CO$_2$ clearance

- **Pressure Assist:**
  - Decelerating flow more comfortable
  - Better synchrony and more physiological
SIMV: Synchronized Intermittent Mandatory Ventilation (Volume Control)
SIMV: Synchronized Intermittent Mandatory Ventilation (Pressure Control)
SIMV: Synchronized Intermittent Mandatory Ventilation (PRVC)
SIMV: Breath Cycle Time

Maquet Pocket Guide, Modes of Ventilation, Servo-I
Inspiratory work per unit volume done during SIMV

![Graph showing work per volume (joules/liter) against percent SIMV support. The graph compares 'Assist' and 'Spont' conditions.](image-url)
SIMV

- **Advantages:**
  - Improved synchrony
  - Preservation of respiratory muscle function
  - Lower mean airway pressures
  - Decreased tendency to develop auto-PEEP

- **Disadvantages:**
  - Increased work of breathing compared to ACV
  - Not shown to be effective for weaning
Pressure Support

- Spontaneous breathing with a ventilator “boost”
- Patient triggers all the breaths
- Flow-cycled:
  - once triggered, the set pressure is sustained until the inspiratory flow tapers

- $V_T$ and RR (minute volume) are a consequence of the patient-related variables (ie. the underlying disease, sedation) plus ventilator settings
Pressure Support

[Diagram showing pressure support parameters and settings]

- Peak Pressure: 23 cmH₂O
- Mean Pressure: 12 cmH₂O
- PEEP: 7 cmH₂O
- RR: 16 breaths/minute
- Ti/Ttot: 0.33
- MVe: 8.9 liters/minute
- VTl: 543 ml
- VTe: 548 ml
- Oxygen Concentration: 35%
- PEEP: 8 cmH₂O
- PS above PEEP: 15 cmH₂O

Additional settings:

- Additional Patient Information
Pressure Support

- Gas flows into lungs at a constant pressure

- Since pressure is constant, the flow will decrease until Inspiratory cycle off (1)

- Pressure will either rise quickly or slowly, depending on Insp rise time (2)
Pressure Support

Advantages:

- Comfortable: patient has greater control over ventilator cycling and flow rates
- Work of breathing is inversely proportional to the level of pressure support

Disadvantages:

- Close monitoring is required
- Neither tidal volume nor minute ventilation is guaranteed
32 Male
MVC – LOC & TBI
GCS: 7
BP: 160/80  P: 70  R: 5
(L) Pupil 5 mm
(R) Pupil 3 mm
Bilateral Breath Sounds
Other trauma exam (-)
Ventilator Settings

Mode: Control
Tidal Volume ($V_T$): 750 mL
Resp Frequency (f): 15 b/min
Insp Flow Rate (V): 30 L/min

Airway Resistance ($R_{AW}$):
10 cm H$_2$O/L/sec

Respiratory System Compliance ($C_{RS}$):
0.05 L/cm H$_2$O
50 mL/cm H$_2$O

Neurosurgery resident:
“ No sedation for Neuro Exam ”
20 min later..

ALARM!
BP: 80/40
P: 120
R: 40
Auto PEEP:

- High respiratory rate, short expiratory time
- Not enough time to exhale → Air Trapping

*Interpretation of waveforms, Waugh, Deshpande, 2007*
Interpretation of waveforms, Waugh, Deshpande, 2007
Determinants of AutoPEEP

- Minute Ventilation ($V_T$ and RR)
- Expiratory Time constant
  Longer I:E ratio = short expiratory time
- High resistance, floppy lung

Clues to diagnosis..

- Increase $P_{\text{Peak}}$ and $P_{\text{Plateau}}$ (VC)
- Decreases in $V_T$ (PC)
- Problems with inspiratory trigger
- Dyssynchrony
- Hemodynamic abnormalities ..
Treatment of AutoPEEP

- Decrease Minute Ventilation (RR, $V_T$)
- Increase Inspiratory Flow / pattern → Increase Expiratory Time
- Treat underlying cause (Bronchodilators, suction)
- Apply extrinsic PEEP
- Sedation
- Disconnect ventilator circuit
56 year old man with SAH, receiving MV using Volume Assist Control for last 36 h. Settings are:

\( V_T: 600 \)  \( R: 24 \)  \( FiO2: 0.4 \)  \( PEEP: 5 \). You decide to switch him to Pressure Support with 22cm Insp Pressure to obtain comparable \( V_T \).

He becomes dyspneic and appears to be triggering the ventilator only 8-10 times/min. Next maneuver should be?
A. Provide sedation and continue current settings
B. Switch from Pressure to Flow triggering
C. Add 5 cmH\(_2\)O additional PEEP and increase until better trigger
D. Switch to SIMV with back up rate of 8 along with PS
E. Return to volume assist Control with backup rate 6/min.
A. Provide sedation and continue current settings
B. Switch from Pressure to Flow triggering
C. Add 5 cmH₂O additional PEEP and increase until better trigger
D. Switch to SIMV with back up rate of 8 along with PS
E. Return to volume assist Control with backup rate 6/min.
Modern Ventilators:

- **Computer Based & Smart**
  - Use complex algorithms

- Airway Pressures (ARDs Net)
- Mode Switch
- Waveform analysis
- Synchrony
- Patient Comfort
- Weaning
- Open Lung Tool
Open Lung Tool (OLT)

Pressure Control Ventilation *
NAVA

Amirali Nader, M.D.
Critical Care Medicine
Suburban Hospital
Johns Hopkins Medicine
Trigger Delay

Data from Jubran et al and Parthasarathy et al

Cycle-off Delay
Asynchrony

Synchrony:

- **Initiation, delivery** and **termination** of the patient’s and the ventilator’s breaths coincide with each other.
Dyssynchrony:

- 20-30% of patients on ventilators exhibit dyssynchrony
- Patients with frequent ineffective triggering may receive excessive levels of ventilatory support
Normal Muscle

Wasted Efforts

Eccentric contractions
Rapid **Disuse Atrophy** of Diaphragm Fibers during asynchronous ventilation:
Usual solution to Patient-Ventilator Asynchrony:

- Adjust Ventilator Settings
- Increase Sedation
- Neuromuscular blockers

Ears → (1920-1990) → Chest

Prolonged ICU stay
Neurally Adjusted Ventilatory Assist: (NAVA)

- New **Spontaneous, Interactive** mode of mechanical ventilation
- Delivers ventilatory assist in **Proportion** to and in **Synchrony** with the patient’s **Edi** signal
Edi Signal:

- **Edi** - Electrical Activity of diaphragm (measured 62.5 times per second)
  - **Edi Peak** – The amount of impulse sent to generate tidal volume breath by breath.
  - **Edi Min** – The tonic contractility of the diaphragm at rest. Physiologic reflection of de-recruitment.
Central nervous system
↓
Phrenic nerve
↓
Diaphragm excitation
↓
Diaphragm contraction
↓
Chest wall, lung and esophageal response
↓
flow, pressure changes

Ideal Technology

Ventilator

Current Technology
Central nervous system

Phrenic nerve

Diaphragm excitation

Diaphragm contraction

Chest wall, lung and esophageal response

flow, pressure changes

Ideal Technology

NAVA

Ventilator

Current Technology
1. NAVA software option – if not already factory-install software can be installed using a PC Card.
2. Edi Module
3. Edi Cable
4. Edi Catheter

Servo-i ventilator
**Edi Catheter Sizes**

<table>
<thead>
<tr>
<th>Size</th>
<th>Length</th>
<th>Age Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size 6 Fr / 49 cm</td>
<td></td>
<td>Neonate</td>
</tr>
<tr>
<td>Size 6 Fr / 50 cm</td>
<td></td>
<td>Neonate</td>
</tr>
<tr>
<td>Size 8 Fr / 100 cm</td>
<td></td>
<td>Pediatric</td>
</tr>
<tr>
<td>Size 12 Fr / 125 cm</td>
<td></td>
<td>Pediatric</td>
</tr>
<tr>
<td>Size 8 Fr / 125 cm</td>
<td></td>
<td>Adult</td>
</tr>
<tr>
<td>Size 16 Fr / 125 cm</td>
<td></td>
<td>Adult</td>
</tr>
</tbody>
</table>
Instructions for catheter:

1. Dip the Edi Catheter in **water** for a few seconds to activate its lubrication prior to insertion, avoiding wetting connectors.
2. Insert Catheter and advance it down the esophagus
3. Confirm placement
Edi Catheter Anatomy:

1. Connection to Edi cable
2. Nutrition feed
3. Evacuation (only 12 and 16 Fr)
4. Reference electrode
5. Electrodes (9)
6. Holes for nutrition/evacuation
7. Inter Electrode Distance (IED)
8. Lumen for electrodes
9. Sump lumen (only 12 and 16 Fr)
10. Feeding lumen
11. Barium strip for X-ray identification
12. Coating for easier insertion and better electrical conductivity (indicated in the picture with light blue)
13. Scale in centimeters from the tip
**Insertion Depth:**

Coefficient for nasal insertion = 0.9  
Coefficient for oral insertion = 0.8

<table>
<thead>
<tr>
<th>Fr/cm</th>
<th>Insertion distance Y for oral insertion</th>
</tr>
</thead>
<tbody>
<tr>
<td>16 Fr</td>
<td>NEX cm · 0.8 + 18 = Y cm</td>
</tr>
<tr>
<td>12 Fr</td>
<td>NEX cm · 0.8 + 15 = Y cm</td>
</tr>
<tr>
<td>8 Fr 125 cm</td>
<td>NEX cm · 0.8 + 18 = Y cm</td>
</tr>
<tr>
<td>8 Fr 100 cm</td>
<td>NEX cm · 0.8 + 8 = Y cm</td>
</tr>
<tr>
<td>6 Fr 50 cm</td>
<td>NEX cm · 0.8 + 3.5 = Y cm</td>
</tr>
<tr>
<td>6 Fr 49 cm</td>
<td>NEX cm · 0.8 + 2.5 = Y cm</td>
</tr>
</tbody>
</table>

D. Rowley, Univ of Virginia, Resp Therapy Dept.
Catheter Insertion:
Edi Catheter Insertion:

Check position of Edi Catheter *like a feeding tube* according to hospital guidelines (i.e. portable CXR)

D. Rowley, Univ of Virginia, Resp Therapy Dept.
Catheter Insertion:

D. Rowley, Univ of Virginia, Resp Therapy Dept.
Good position: P-wave / QRS Progression
Too Deep... (pull catheter back)
Too Shallow.. (advance catheter)
Factors affecting Edi signal:

- Muscle relaxants / paralytics
- CNS depressant drugs, sedation
- Hyperventilation
- High PEEP, High support pressure
Volume Control with Edi:

- Pressure
- Flow
- Volume
- Edi Catheter
NAVA Pre-view: unmasking asynchrony
Same patient on NAVA:

Breath to Breath Synchrony
Decreased Airway Pressure
Asynchrony during VC:

**Volume Control**

- Ppeak (cmH₂O): 59
- Pmean (cmH₂O): 28
- PEEP (cmH₂O): 2
- RR (b/min): 26
- O₂ (%) C: 34
- MVe (l/min): 4.9
- VTi (ml): 232
- VTe (ml): 65
- Edi peak (µV): 50
- Edi min (µV): 0.3

**Additional settings**

- O₂ conc. 35%
- PEEP 5 cmH₂O
- Resp. Rate 15 b/min
- Tidal Volume 220 ml
Same Patient on NAVA:

D. Rowley, Univ of Virginia, Resp Therapy Dept.
0.1-2.0 micro volts
Starting NAVA: Preview Screen
Increase NAVA level until **Pest peak** = current PAP

Estimated Ppeak (Pest) in NAVA = NAVA Level x (Edi peak – Edi min) + PEEP
Activate NAVA mode

Monitor:
- $V_T$
- Edi peak
- PAP
- VS and WOB

Increasing NAVA will result in:
Decrease in Edi Peak, stable Vt, and stabilization of PAP

D. Rowley, Univ of Virginia, Resp Therapy Dept.
NAVA Inspiration:

- Triggering of a breath is either **Edi**, **flow** or **pressure** trigger.

- Even if the breath is triggered on flow or pressure, the breath delivered to the patient remains proportional to the patient’s Edi signal.

- **1st** come **1st** serve basis

1: Edi Triggered Breath
2: Flow Triggered Breath
NAVA Inspiratory Trigger:

- NAVA is triggered by an increase in Edi from the Edi minimum and not at any absolute level of Edi

Set high enough to avoid noise interference

Here, vent will provide support when Edi above 0.7
NAVA Expiration:

- If the **pressure** increases 3 cmH2O above the inspiratory target pressure
- When the Edi signal decreases **below 70%** of the peak value during the ongoing inspiration
- Also, If the upper pressure/time limit is exceeded (time for adults = 2.5 sec)
The NAVA signal – what it means

- NAVA level is the factor by which the Edi signal is multiplied to adjust the amount of assist delivered to the patient.

- NAVA level varies for different patients because they will require different assist levels.

- Typically 1.0 - 4.0 cmH20/μV

Am J Respir Crit Care Med 2001
Nat Med 1999; 5(12): 1433-1436
The pressure delivered by the ventilator is derived from the following formula:

\[ \text{NAVA level} \times (\text{Edi signal} - \text{Edi min}) + \text{PEEP} \]
**NAVA**: Physiologic Principles

- Neural signal is increased as respiratory muscles weaken relative to load.
- Synchrony in assist delivery is inherent.
- Unloading can be done objectively.
- Proportional assist gives freedom for variable breathing.
- Patient ‘Oscillator’ controls breath timing and tidal volume.
What we know so far...

- NAVA Improves patient ventilator synchrony (potentially less sedation)
- Allows real time monitoring of respiratory drive
- Adapts to patient’s altered respiratory drive and reflexes
- Less damage to muscles, less disuse atrophy

Chest 2007; 131(3): 711-717
Applications

- Good tool for weaning..
  - Can watch Edi signal decrease as respiratory function improves

- Proportional assist gives freedom for variable breathing

- The patient will control Tidal Volume & Respiratory Rate
Applications:

- Spinal Cord Injury
- Cardiothoracic surgery
- Edi signal as a tool to detect over-sedation and neuromuscular recover (ie. Guillan Bare)
Limitations:

- Lack of large randomized clinical trials
- Uncertainty whether synchrony leads to better outcome
- Reliability of equipment – NAVA Catheter integrity after prolonged ventilation
- Cost of equipment and resources