INTRODUCTION TO INVASIVE MECHANICAL VENTILATION

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GOD IS A PULMONOLOGIST

- 7 Then the LORD God formed a man from the dust of the ground and breathed into his nostrils the breath of life, and the man became a living being.

GENESIS 2:7

THE VENTILATOR

The Ventilator

An air pump that is well dressed and has jewerly on

Remember Andreas Vesalius

- **“ But that life may be restored to the animal,an opening must be attempted in the trunk of the trachea, into which a tube of reed or cane should be put; you will then blow into this, so that the lung may rise again and take air”**

De Humani Corporis Fabrica 1543

Figure 1. (*Left*) Woodcut of the only known firsthand likeness of Andreas Vesalius (reprinted from Reference 48). (*Right*) Frontispiece of *De Humani Corporis Fabrica* (reprinted from Reference 49).

Am J Respir Crit Care Med, 2015
https://www.atsjournals.org/doi/abs/10.1164/rccm.201503-0421PP

Published in: Arthur S. Slutsky; *Am J Respir Crit Care Med* 1911106-1115.
DOI: 10.1164/rccm.201503-0421PP

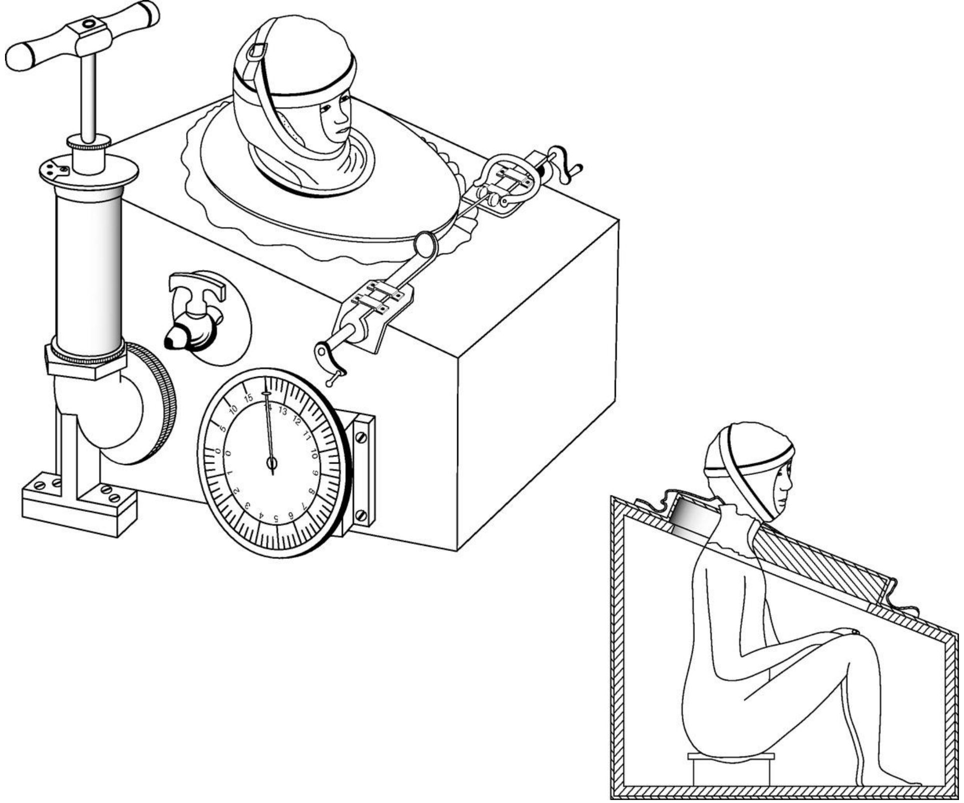

Figure 2. Body-enclosing box. One of the first known body-enclosing boxes; patented by Alfred Jones in 1864. Reprinted from Reference 12.

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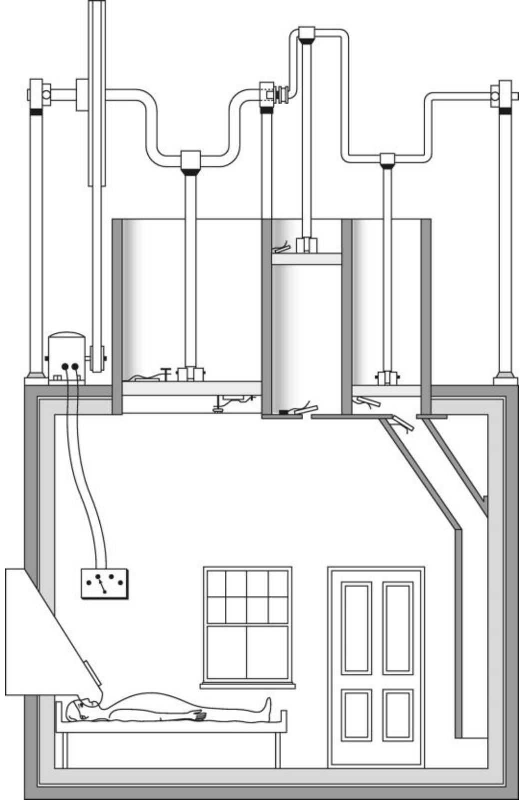

Figure 3. Respirator room. Pressure changes in the room were generated by huge pistons, which created pressure changes in the thoracic cavity, which in turn caused gas to move into and out of the patient who was connected via a manifold to a fresh gas supply outside the room. Adapted from Reference 50.

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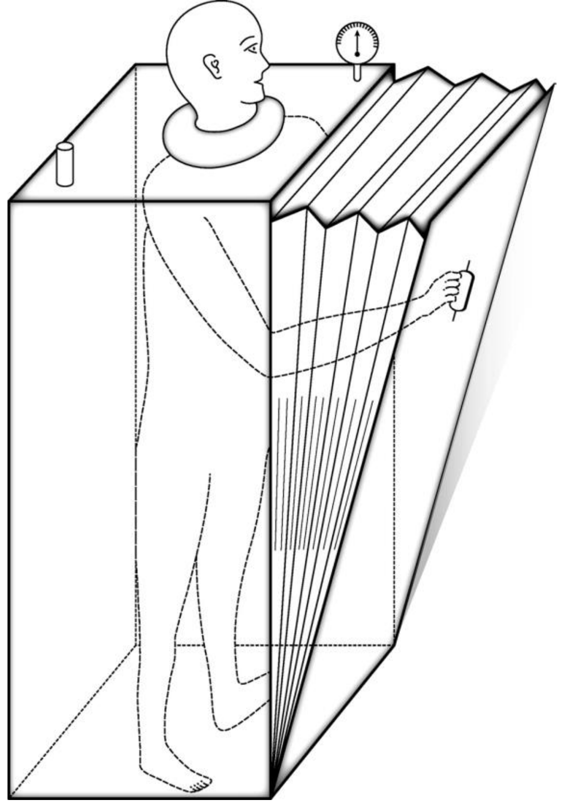

Figure 4. Pneumatic chamber: Patented by Wilhelm Schwake in Germany in 1926 (51). Schwake was concerned with precise matching of the ventilator and the patient’s breathing pattern. Reprinted from Reference 13.

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THE NEW VENTILATOR

Who needs it?

- Patients that require airway protection
- Patients with respiratory failure

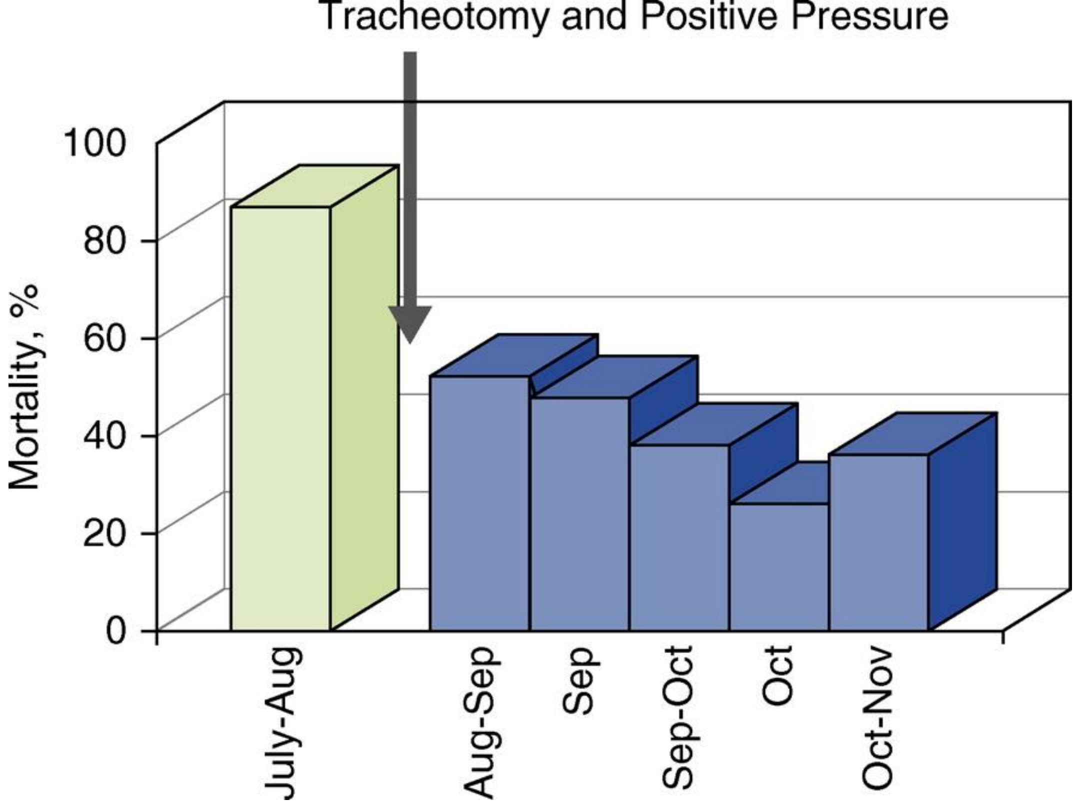

Figure 5. Mortality rate from bulbar polio. The mortality rate in July and August 1952 (up to August 27) for bulbar polio in the Blegdams Hospital was 87%. On August 27, 1952, tracheotomy and positive pressure ventilation were introduced (*arrow*). Mortality immediately dropped dramatically and was about 40% in the ensuing months. Adapted by permission from Reference 16.

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OVERVIEW

- The term “respiratory failure" did not appear in the medical literature until the early 1960s
- advances in blood gas analysis and life support have enabled us to define and treat this exigency
- about 50% of patients in ICUs receive ventilatory support at some point

Respiratory failure

- 2 main types of respiratory dysfunction
  - Lung failure(type I)
  - Pump failure(type II)

Tissue Oxygenation

Respiratory system can be organized into 2 main components

1. Airpump:
   - Respiratory centers in the brain
   - Chest wall
   - respiratory muscles
   - Conducting airways
2. Gas exchanger: component
   - pulmonary parenchyma
     - respiratory bronchioles
     - alveolar ducts
     - alveolar sacs (alveoli).

3 processes of adequate tissue oxygenation

- Transfer of O_2 across alveolus
- Transport of O_2 to the tissues via cardiac output
- Removal of CO_2 from the blood to alveolus to environment

What is Mechanical Ventilation ?

- Using positive pressure to deliver a predetermined mixture of air(Oxygen and other gases) into the central airways which then flows into the alveoli and thereafter allowing for removal of carbondioxide

When to initiate Mechanical Ventilation

- Don’t delay !!

- The intubation process can be dangerous.

“The best soldier available leads”

- Always have a plan B
- **Must have a queen or king available**

The Respiratory Therapists

Queens/Kings of Mechanical Ventilation

After the Intubation

Select initial mode-Make it simple and safe for the patient

Key terms

- **Tidal Volume**
- **PEEP(Positive end expiratory pressure)**
- **PEEPi(Intrinsic positive end expiratory pressure,autoPEEP)**
- **FiO2(Fraction of inspired oxygen)**
- **Plateau pressure**
- **Peak airway pressure**
- **Driving pressure(P_p –PEEP)**

MODES

- Volume-limited assist control ventilation
- Pressure-limited assist control ventilation
- Synchronized intermediate monitoring ventilation–pressure support ventilation

DEMONSTRATION

Volume-limited assist control ventilation (Volume –controlled or Volume Cycle)

Set: Peak flow rate, flow pattern, **Tidal volume, respiratory rate, PEEP, FiO2**

Simplest for initiating ventilation

Modes:CMV(Controlled mechanical ventilation),AC(Assist-control),IMV,SIMV

Assist Control mechanical ventilation

Set: Minute ventilation(RR,VT)

Patient can increase minute ventilation by triggering additional breaths.

All breaths receive the set tidal volume from the ventilator

Simplest for initiating ventilation

Controlled mechanical ventilation

Patient is entirely dependent on the ventilator with a set respiratory rate and tidal volume

Requires heavy sedation and paralysis. Patient may be in a comatose state.

Pressure regulated volume control(PRVC)

Tidal volume is set and the pressure needed to deliver rate changes depending on lung compliance and patient effort

Intermittent mandatory ventilation(IMV)

Minimum minute Ventilation is determined by setting rate and tidal volume but patient is able to increase minute ventilation

Synchronized Intermittent Mandatory Ventilation(SIMV)

Ventilator breaths are synchronized with patient's effort

Familiarity Saves lives

Stick to the simplest mode and become an expert

Pressure limited ventilation

Set:The maximum inspiratory pressure, I:E ratio, respiratory rate, PEEP, FiO_2**(Tidal volume not set)**

Tidal volume is variable

Pressure limited Controlled ventilation

The patient has no say.

Pressure limited Assist-control ventilation

The patient has a say but pressure is limited on additional breaths.

Which is better?

Pressure or Volume?

Familiarity Saves lives

Stick to the simplest mode and become an expert

You have intubated and initiated Ventilation

- Make sure the patient is comfortable
- Ensure safety
- Confirm acceptable endotracheal tube placement

- Check gas exchange and ventilation with arterial blood gas testing
- Monitor patient for improvement with adjustment as necessary
- Monitor end-tidal CO_2 continuously if possible

- Monitor patient for complications

Setting FiO2/Rate

- Use what the patient was Requiring prior to intubation as a guide
- Remember oxygen can be a “toxin”
- If unsure start high and rapidly titrate downward or upward using pulse oximetry prior to arterial blood gas
- Do not set and forget

TIDAL VOLUME

Low tidal volume ventilation in patients with acute respiratory distress syndrome

Initial ventilator settings

Calculate predicted body weight (PBW)

Male =	50 + 2.3 [height (inches) – 60] **or**
	50 + 0.91 [height (cm) – 152.4]
Female =	45.5 + 2.3 [height (inches) – 60] **or**
	45.5 + 0.91 [height (cm) – 152.4]

Set mode to volume assist-control

- Set initial tidal volume to 6 mL/kg PBW

Set initial ventilator rate ≤35 breaths/min to match baseline minute ventilation (to avoid hypercapnia)

Subsequent tidal volume adjustment

Plateau pressure goal: Pplat ≤30 cm H_2O

Check inspiratory plateau pressure with 0.5 second inspiratory pause at least every four hours and after each change in PEEP or tidal volume.

- If Pplat >30 cm H_2O, decrease tidal volume in 1 mL/kg PBW steps to 5 or if necessary to 4 mL/kg PBW.
- If Pplat <25 cm H_2O and tidal volume <6 mL/kg, increase tidal volume by 1 mL/kg PBW until Pplat >25 cm H_2O or tidal volume = 6 mL/kg.
- If breath stacking (autoPEEP) or severe dyspnea occurs, tidal volume may be increased to 7 or 8 mL/kg PBW if Pplat remains ≤30 cm H_2O.

Arterial oxygenation and PEEP

Oxygenation goal: PaO_2 55 to 80 mmHg or SpO_2 88 to 95%

Use these FiO_2/PEEP combinations to achieve oxygenation goal:

FiO_2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
PEEP	5	5 to 8	8 to 10	10	10 to 14	14	14 to 18	18 to 24

PEEP should be applied starting with the minimum value for a given FiO_2.

FiO_2: fraction of inspired oxygen; PaO_2: arterial oxygen tension; PEEP: positive end-expiratory pressure; Pplat: plateau pressure; SpO_2: oxyhemoglobin saturation.

Adapted from: Ventilation with lower tidal volumes as compared with traditional tidal volumes for acute lung injury and the acute respiratory distress syndrome. The Acute Respiratory Distress Syndrome Network. N Engl J Med 2000; 342:1301.

Summary of Ventilator Procedures in the Lower- and Higher-PEEP Groups.

Table 1. Summary of Ventilator Procedures in the Lower- and Higher-PEEP Groups.*

Procedure	Value
Ventilator mode	Volume assist/control
Tidal-volume goal	6 ml/kg of predicted body weight
Plateau-pressure goal	≤30 cm of water
Ventilator rate and pH goal	6–35, adjusted to achieve arterial pH ≥7.30 if possible
Inspiration:expiration time	1:1–1:3
Oxygenation goal	
PaO_2	55–80 mm Hg
SpO_2	88–95%
Weaning	Weaning attempted by means of pressure support when level of arterial oxygenation acceptable with PEEP ≤8 cm of water and FiO_2 ≤0.40

Allowable combinations of PEEP and FiO_2†														
Lower-PEEP group														
FiO_2	0.3	0.4	0.4	0.5	0.5	0.6	0.7	0.7	0.7	0.8	0.9	0.9	0.9	1.0
PEEP	5	5	8	8	10	10	10	12	14	14	14	16	18	18–24
Higher-PEEP group (before protocol changed to use higher levels of PEEP)														
FiO_2	0.3	0.3	0.3	0.3	0.3	0.4	0.4	0.5	0.5	0.5–0.8	0.8	0.9	1.0	
PEEP	5	8	10	12	14	14	16	16	18	20	22	22	22–24	
Higher-PEEP group (after protocol changed to use higher levels of PEEP)														
FiO_2	0.3	0.3	0.4	0.4	0.5	0.5	0.5–0.8	0.8	0.9	1.0				
PEEP	12	14	14	16	16	18	20	22	22	22–24				

* Complete ventilator procedures and eligibility criteria are listed in the Supplementary Appendix (available with the full text of this article at www.nejm.org) and at www.ardsnet.org. PaO_2 denotes partial pressure of arterial oxygen, SpO_2 oxyhemoglobin saturation as measured by pulse oximetry, FiO_2 fraction of inspired oxygen, and PEEP positive end-expiratory pressure.

† In both study groups, additional increases in PEEP to 34 cm of water were allowed but not required after the FiO_2 had been increased to 1.0 according to the protocol. The combinations of PEEP and FiO_2 used with PEEP values of less than 12 cm of water were eliminated in the higher-PEEP group after 171 patients had been enrolled in this group.

The National Heart, Lung, and Blood Institute ARDS Clinical Trials Network. N Engl J Med 2004;351:327-336.

The NEW ENGLAND JOURNAL of MEDICINE

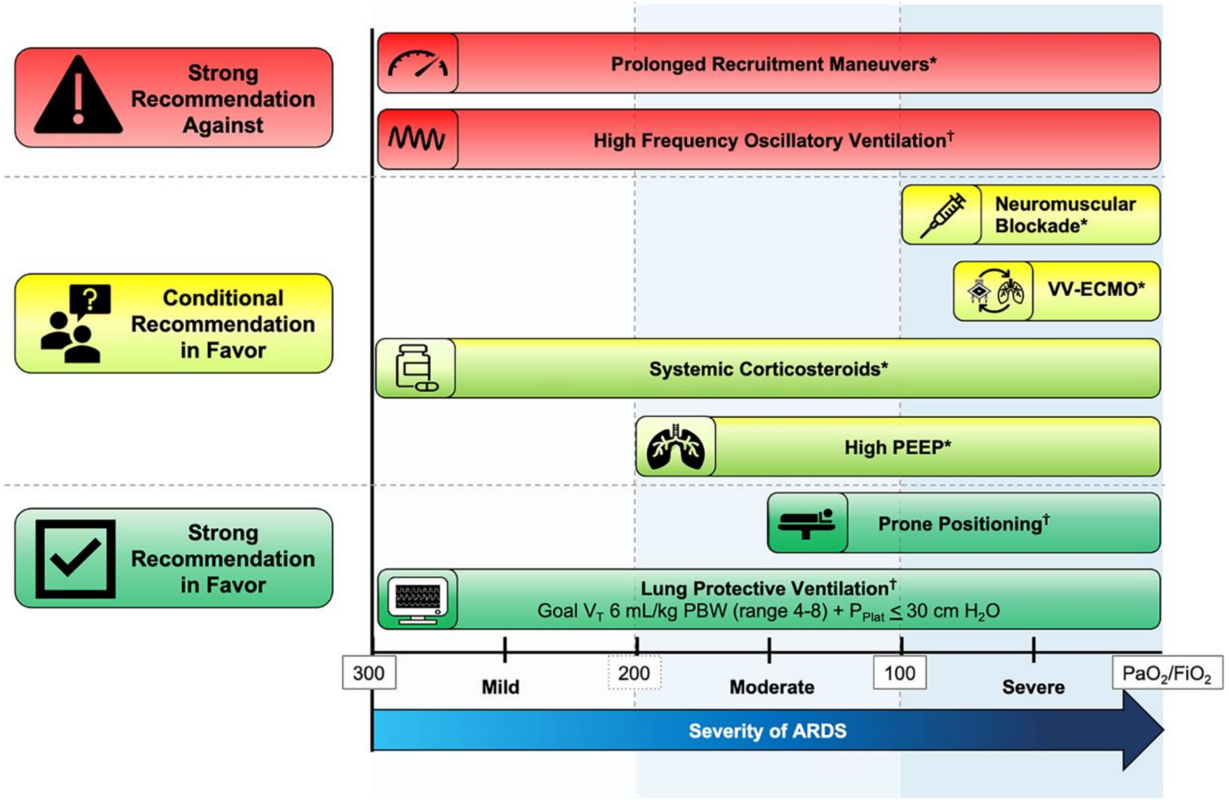

Figure 1. Current American Thoracic Society guidelines for the management of acute respiratory distress syndrome. *New or updated recommendations in current guideline. †Recommendations addressed in 2017 guideline. ARDS = acute respiratory distress syndrome; FiO2 = fraction of inspired oxygen; PaO2 = partial pressure of oxygen; PBW = predicted body weight; PEEP = positive end-expiratory pressure; Pplat = plateau pressure; VT = tidal volume; VV-ECMO = venovenous extracorporeal membrane oxygenation.

Am J Respir Crit Care Med, 2024
https://www.atsjournals.org/doi/abs/10.1164/rccm.202311-2011ST

Published in: Nida Qadir; Sarina Sahetya; Laveena Munshi; Charlotte Summers; Darryl Abrams; Jeremy Beitler; Giacomo Bellani; Roy G. Brower; Lisa Burry; Jen-Ting Chen; Carol Hodgson; Catherine L. Hough; Francois Lamontagne; Anica Law; Laurent Papazian; Tai Pham; Eileen Rubin; Matthew Siuba; Irene Telias; Setu Patolia; Dipayan Chaudhuri; Allan Walkey; Bram Rochwerg; Eddy Fan; *Am J Respir Crit Care Med* 20924-36.
DOI: 10.1164/rccm.202311-2011ST

Lung Protective Ventilatory Strategies

- The lung can be injured by positive pressure ventilation (PPV) via several mechanisms- ventilator-induced lung injury (VILI)
  - overdistention injury when lung units are physically stretched beyond their normal maximums
    - occurs when end-inspiratory transpulmonary pressures (and resulting end-inspiratory volumes) exceed the normal maximum of 30 to 35 cmH_2O
  - collapsed lung units are subjected to shear stress when repetitively opened and closed during PPV
  - tidal stretch injury that occurs with repetitive use of tidal volumes above the normal of 5 to 6 mL/kg(controversial)
- These injuries likely occur predominantly in healthier regions of the lung, which receive the bulk of mechanical ventilatory support
- The "art" of providing PPV is thus to support adequate gas exchange without causing regional VILI.

Fancy Modes

Airway pressure release ventilation (APRV)

- APRV uses a long inflation period with superimposed spontaneous breathing
- thus an alternative to tidal volume and PEEP to raise mean airway pressure
- Two RCTs evaluated APRV
  - One showed benefit (but with a seriously flawed control group strategy)
  - other showed comparable outcomes to conventional ventilation

High-frequency ventilation (HFV)

- HFV uses very small tidal volumes and rapid breathing frequencies (up to 900 breaths/minute). Gas transport is thus by nonconvective flow, and substantial mean pressures can be provided with very small tidal distentions
  - HFV in the adult has been evaluated in a single RCT conducted in the late 1990s, and the results showed only a "trend" in favor of HFV

(The other fancy staff is for star wars for now)

•MacIntyre NR, et al.Respir Care. In press.

•Derdak S, Mehta S, Stewart TE, et al. Am J Respir Crit Care Med. 2002;166:801-808.

Mechanical ventilation during anesthesia in adults

- Modes
  - Volume controlled ventilation
  - Pressure controlled ventilation
  - Pressure control with volume guarantee
  - Pressure support-LMA

- Oxygen: Easy does it

Complications of Mechanical Ventilation

- Pulmonary
  - Barotrauma
  - Ventilator associated Lung injury
  - Pneumonia
  - Endotracheal tube related complications
  - Respiratory muscle weakness
  - Reduced mucociliary motility
- NonPulmonary
  - Cardiovascular:Hypotension,VTE
  - GI:Ulcers,Hypomotility,acalculous cholecyctitis,erosive esophagitis
  - AKI
  - Neurologic:Neuromuscular weakness, increased ICP, disordered sleep
  - Equipment malfunction

WEANING

That is for another day