All I’ve Learned About Weaning Patients From Mechanical Ventilation

FOCUS Pittsburgh

John J. Marini
University of Minnesota
Minneapolis / St. Paul
Until recently, the subject has been seemingly dead or sleeping…
Epidemiology of Weaning Outcome according to a New Definition. The WIND Study.

Am J Respir Crit Care Med. 2017 Mar 15;195(6):772-783

Béduneau G1,2, Pham T3,4,5, Schortgen F6, Piquilloud L7,8, Zogheib E9,10, Jonas M11, Grelon F12, Runge I13, Nicolas Terzi14,15,16,17, Grangé S1, Barberet G18, Guitard PG19, Frat JP20,21,22, Constan A6, Chretien JM23, Mancebo J24, Mercat A7, Richard JM25, Brochard L26,27. WIND (Weaning according to a New Definition) Study Group and the REVA (Réseau Européen de Recherche en Ventilation Artificielle) Network ‡.

Abstract

RATIONALE: The weaning process concerns all patients receiving mechanical ventilation. A previous classification into simple, prolonged, and difficult weaning ignored weaning failure and presupposed the use of spontaneous breathing trials.

OBJECTIVES: To describe the weaning process, defined as starting with any attempt at separation from mechanical ventilation and its prognosis, according to a new operational classification working for all patients under ventilation.

METHODS: This was a multinational prospective multicenter observational study over 3 months of all patients receiving mechanical ventilation in 36 intensive care units, with daily collection of ventilation and weaning modalities. Pragmatic definitions of separation attempt and weaning success allowed us to allocate patients in four groups.

MEASUREMENTS AND MAIN RESULTS: A total of 2,729 patients were enrolled. Although half of them could not be classified using the previous definition, 99% entered the groups on the basis of our new definition as follows: 24% never started a weaning process, 57% had a weaning process of less than 24 hours (group 1), 10% had a difficult weaning of more than 1 day and less than 1 week (group 2), and 9% had a prolonged weaning duration of 1 week or more (group 3). Duration of ventilation, intensive care unit stay, and mortality (6, 17, and 29% for the three groups, respectively) all significantly increased from one group to the next. The unadjusted risk of dying was 19% after the first separation attempt and increased to 37% after 10 days.

CONCLUSIONS: A new classification allows us to categorize all weaning situations. Every additional day without a weaning success after the first separation attempt increases the risk of dying.
CONCLUSIONS: The guideline panel provided recommendations for inspiratory pressure augmentation during an initial SBT, protocols minimizing sedation, and preventative NIV, in relation to ventilator liberation.
Official Executive Summary of an American Thoracic Society/American College of Chest Physicians Clinical Practice Guideline: Liberation from Mechanical Ventilation in Critically Ill Adults

Gregory A. Schmidt, Timothy D. Girard, John P. Kress, Peter E. Morris, Daniel R. Ouellette, Waleed Alhazzani, Suzanne M. Burns, Scott K. Epstein, Andres Esteban, Eddy Fan, Miguel Ferrer, Gilles L. Fraser, Michelle Ng Gong, Catherine L. Hough, Sangeeta Mehta, Rahul Nanchal, Sheena Patel, Amy J. Pawlik, William D. Schweickert, Curtis N. Sessler, Thomas Strem, Kevin C. Wilson, and Jonathon D. Truwit; on behalf of the ATS/CHEST Ad Hoc Committee on Liberation from Mechanical Ventilation in Adults

This official clinical practice guideline of the American Thoracic Society (ATS) and the American College of Chest Physicians (CHEST) was approved by the ATS Board of Directors, December 2016, and by the CHEST Board of Regents, October 2016

Conclusions: The panel provides recommendations regarding liberation from mechanical ventilation. The details regarding the evidence and rationale for each recommendation are presented in the American Journal of Respiratory and Critical Care Medicine and Chest.
Better to remain silent and be thought a fool, than to speak out and remove all doubt.

- Abraham Lincoln
What Have We Really Learned?

General Principles

- Do not let patient work too hard or too little.
- Keep an appropriate fluid balance.
- Pay attention to cardiac issues.
- Restore diurnal and sleep rhythms.
  - Mobilize by day, sleep at night.
- Prevent and treat delirium.
- Minimize sedation but avoid asynchrony.
- Test your assumptions with daily breathing trials.
What Have We Really Learned?

General Principles for the MD & RT

• Do Not Delay Progress
• Pay Close Attention to Post-Extubation

If you're not part of the solution, you're part of the problem.

~ African Proverb
Long Sought Goals in Weaning

• Perfect predictive index
• Easy formula for preparing the patient
• Ideal weaning mode
  – Foolproof
  – Effective
  – Works for everybody

Return on investment has not been very impressive…
Predicting Success in Weaning From Mechanical Ventilation

Maureen Meade, Gordon Guyatt, Deborah Cook, Lauren Griffith, Tasnim Sinuff, Carmen Kergl, Jordi Mancebo, Andres Esteban and Scott Epstein

Chest 2001;120;400S-424S

$V_E$, $V_T$, frequency, $P_{0.1}$, $P_{\text{max}}$, Pressure-time product... etc

Judging by areas under the receiver operator curve for all variables, none of these variables demonstrate more than modest accuracy in predicting weaning outcome.
Liberation Sequence

• Preparation
• Evaluation
• Withdrawal of Support
  – Ventilator
  – Endotracheal Tube
• Peri-Extubation Care
Why Does Extubation Fail?

- **Respiratory**
  - Imbalance of capability/demand
    - Secretion Retention
    - Dynamic Hyperinflation / Auto-PEEP
    - Bronchospasm
    - Upper airway obstruction
    - Atelectasis

- **Cardiac**
  - Lung edema
  - Blood Translocation
  - Ischemia / Diastolic Dysfunction
  - Arrhythmia

- **Mental Issues / Sedation & Delirium**
Clinician-Perceived *Reasons* for Re-intubation Decision

- Inadequate ventilatory capability for demand
- $O_2$ desaturation and/or $CO_2$ retention
- Arrhythmia

*Key Causes of Post-extubation Distress*

- Retention of airway secretions
- Upper airway dysfunction
- Marked fluid excess (positive fluid imbalance)
- Inadequate cardiovascular reserve

*Often Best Revealed After Extubation*
Important Considerations
Before Extubation

- Electrolytes
- Cardiovascular status
- Nutrition
- Hydration
- Distension
- Comfort

Trajectory

- Infection
- Secretions
- Position
- Anxiolysis
- Sedation
- Sleep
Congestion Precipitated by Breathing Effort is Often *Diastolic* Dysfunction

LeMaire, *Anesthesiology* 1987
Detection of Cardiac Dysfunction By NT-Pro BNP in COPD

![Graph showing cardiac dysfunction and no cardiac dysfunction with NT-proBNP levels over time.](image)

Use of N-terminal pro-brain natriuretic peptide to detect acute cardiac dysfunction during weaning failure in difficult-to-wean patients with chronic obstructive pulmonary disease *

Grasso, Salvatore; Leone, Antonio; De Michele, Michele; Anaclerio, Roberto; Cafarelli, Aldo; Ancona, Giovanni; Stripoli, Tania; Bruno, Francesco; Pugliese, Paolo; Dambrosio, Michele; Dalfino, Lidia; Di Serio, Francesca; Fiore, Tommaso

DOI: 10.1097/01.CCM.0000250391.89780.64
De-Conditioning

Ventilator Support
Fluid Retention
Unsuspected Retention of Secretions
No Data??

Caution
Mind your head

E B M

No Evidence??
Preparation

- Encourage sleep; Use hypnotics to complement sedation
- Daily wake-up during full support
- Diurnal rhythms, light modulation, noise reduction
- Relieve discomfort—skeletal & visceral (bowel, bladder)
  - Opiates relieve pain and improve depth of breathing (↓ f/Vt)
- Early conversion to dexmedetomodine
- Mobilize to the extent possible
- Re-establish “baseline” fluid balance
  - Consider albumin and furosemide (drip) / CVVH
- Address cardiac issues—ischemia, rhythm, CHF
- Rx infection, secretions, pleural effusions, anemia
An Often Overlooked Cause of Pain & Agitation

Position of Body & Head Analgesic Spray
Chair* Positioning

* 70°
Obesity, Auto-PEEP & Position

Lemyze *Crit Care Med* 2013
Upright Sitting Position May Reduce Gas Trapping

Lemyze *Crit Care Med* 2013
Preparation Tricks (?)

• Consider depakote, quetiapine, risperidone, olanzepine and dexmedatomidine (Precedex) for delirious or combative patients
  – Hydromorphone often better than fentanyl (‘D&D’)
  – Reduce benzodiazepine use

• Consider anti-arrhythmic & ischemia prophylaxis

• Consider trial of methylphenadate (Ritalin) modafenil (Provigil), for patients slow to awaken

• Inspect the central airway prior to attempt in long ventilated patients
Liberation Sequence

• Preparation
• *Evaluation*
• Withdrawal of Support
  – Ventilator
  – Endotracheal Tube
• Peri-Extubation Care
‘Snapshot’ (Static) Predictive Indicators in Weaning

- NIF more negative than -20 cm H\textsubscript{2}O
- VC > 10 ml/kg
- V\textsubscript{E} < 10 L/min
- Respiratory rate < 30 - 35
- V\textsubscript{T} > 5 ml/kg
- f/ V\textsubscript{T} ratio < 100
- Able to double resting minute ventilation

All are brief assessments of load and/or capability of respiratory pump
Elevated RSBI...Better Than f or $V_E$
...But Many False Positives

Many Patients Can Succeed Despite Shallow Breathing
Well Compensated Restrictive Disease Often Shows Relatively ‘Rapid Shallow Breathing’

Tobin *Chest* 1983
Trends Are Often Better Than Point Predictors of Eventual Outcome
Breathing *Pattern* Components

- Minute Ventilation
- Respiratory Rate
- Tidal Volume
- Inspiratory Time Fraction (Ti/Ttot)
- f/Vt
- Esophageal Pressure
- Edi
- P$_{0.1}$

**Inputs**
*(Drive & Effort)*

**Outputs**
*(Mechanics & Timing)*
Breathing Pattern Variability

• Innate characteristic of health
  – Breath-to-breath variation
  – Complexity
• Improves pulmonary gas exchange
• May lessen atelectasis

• *Declines as load/capacity ratio increases*
• Normally declines during sleep
• Influenced by mode and level of support
A Useful Weaning Indicator?
f/V_T Equilibrates *Relatively Quickly* Compared to P_{es} Effort (Swing)

From Jubran and Colleagues
But RSBI Often Varies During A Trial…

Zamora 2012
\( P_{es} \) Swing Amplitude and Trend Predict Weaning Outcome

From Jubran and Colleagues
P_{es} Swings vs. RSBI-- Success

Jubran, Grant, Laghi, et al.: Esophageal Pressure during Weaning
P_{es} Swings vs. RSBI -- Failure
Variation of Breathing Pattern Helps Predict Weanability

Wysocki 2006
Edi (NAVA) Catheter
Variability Increases as Muscles Are Unloaded

More NAVA, less load & more variation
But Variability May Also Increase In Response to *Distress*
No Data??

No ‘Evidence’??
Prediction…Key Indicators

- Prior Variability in Requirements
- Correlate RSBI with $V_E$
  - If $V_E$ and RSBI both increase $\rightarrow$ exercise response
  - If $V_E$ does not rise, high RSBI suggests problems
- Observe Variation of Breathing Patterns
  - $V_E$ before trial
  - Pattern of breathing on low level of PSV
- Observe ‘Cough Inspiratory Capacity’ & PEF?
  - If $> 2 \times V_T$ $\rightarrow$ good power reserve
Normal Exercise Response

...Falling, then $\text{Rising } f/V_T$
Readiness Evaluation

• **Awake, oxygenated, stable & optimally prepared?**

• **Power Requirement**
  – Minute Ventilation...minimum sustained value is important
  – Work per liter (mean airway pressure)

• **Power Reserve**
  – Cough inspiratory capacity (catheter or saline stimulation)
  – Peak expiratory flow (catheter stimulation)
  – *Current & prior* minute ventilation levels and variation (over 6-8 hours)
    • Sleep vs. awake

• **Spontaneous Breathing Test (SBT)**
  – Variation of tidal volume, $V_E$, I:E ratio
  – Assess f/Vt ratio in relation to:
    • Respiratory compliance, *chronic* neuromuscular background
    • *Directional* change in minute ventilation
Liberation Sequence

- Preparation
- Evaluation
- Withdrawal of Support
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  - Endotracheal Tube
- Peri-Extubation Care
Ventilator Discontinuation: Why Are We Still Weaning?

identify when mechanical ventilation can be discontinued. It is time to stop weaning from the ventilator and to start weaning old-fashioned ideas.

Diagram:

- Full or Partial Support
  - Treat Underlying Disease
    - Stop Sedation
      - Spontaneous Breathing Trial
        - Evaluate for Extubation
        - Determine Cause of Failure

Dean R. Hess, Ph.D., R.R.T.
Massachusetts General Hospital
Harvard Medical School
Boston, Massachusetts

Neil R. MacIntyre, M.D.
Duke University Medical Center
Durham, North Carolina
“Judging by that old fashioned bulb, your idea must be outdated.”
Does Mode or Method Matter?

- Literature suggests *No*
  - Spontaneous breathing trial (SBT) on minimal support
  - Up or Down decision to extubate based on SBT
    - Bi-Pap if needed afterward
- Experience suggests *Yes*
  - Cardiac Issues
  - Emotional issues
  - Debility

Graded PSV, PAV, NAVA
It’s All In Just *How* You Do It
A Few Years Later...
A Multicenter Randomized Trial of Computer-driven Protocolized Weaning from Mechanical Ventilation

François Lellouche, Jordi Mancebo, Philippe Jolliet, Jean Roeseler, Frédérique Schortgen, Michel Dojat, Belen Cabello, Lila Bouadma, Pablo Rodriguez, Salvatore Maggiore, Marc Reynaert, Stefan Mersmann, and Laurent Brochard

Conclusions: The specific computer-driven system used in this study can reduce mechanical ventilation duration and ICU length of stay, as compared with a physician-controlled weaning process.
Nice Early Try
Where ventilator technology has
*currently* brought us…
Emerging Economic Realities

- Fewer Trained Personnel per Patient
  - Observation
  - Intervention
- Faster Hospital Throughput
- More Demands For Documentation
  $\implies$ Less Time at Bedside
Optimized Management

How Do We Time Our *Therapeutic* ‘Flip’?

- Rescue Phase
- +
- Stabilization Phase
- Re-loading (Strengthening) Phase
- Recovery Phase
Key Principles of ICU Management

- Therapeutic efficacy depends on *appropriate & early* intervention.
- Clinician must *weight and integrate* all important factors.
- *Timely mid-course corrections* are vital.
Sustaining a Bedside Presence is Problematic for Today’s Caregivers
Electronic Medical Records Are Part of the Problem

Need for data entry — Detachment from the patient and bedside care giving team
‘Closed Loop’ Automation Helps Us Stay Vigilant & React Quickly
Challenges for Automated Modes Of Ventilation

• Integrate all vitally relevant information
• Appropriate reactive timing of adjustments
• Correct intervention paradigm for the task
• Patient acceptance of imposed changes
Automated Approaches To Ventilator Weaning

• Let the patient determine ventilation rhythm
• Coordinate *airway* pressures within the individual tidal cycle
• Evaluate the breathing pattern and exhaled CO$_2$ & readjust to keep in desired ranges
• Withdraw unnecessary support
Proportional Assist Synchronizes With & Mirrors Muscular Effort

Assessed By Mechanical Output

20-80%
**PCV vs. PAV**

*Off-switch & Power*

From Javier Fernandez

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**PCV**

15 cmH2O

**PAV+**

at 75%
Phrenic nerve traffic guides the breathing support provided.

Diaphragmatic EMG may offer diagnostic info.
NAVA Provides Flexible Energy Boost Response To Tidal Efforts

Can the Patient & Caregiver Be Trusted With Control?
Potential Applications of ‘Closing The Loop’ By Automation

- **Safely** Optimize Physiological Targets
- Minimize Time of Support (‘Weaning’)
- Avoid
  - Asynchrony
  - VILI
  - Unnecessary supplemental oxygen
Adaptive Support Manipulates Pressure & Machine Rate to Keep in Desired Range
Automated Modes

Candidates for Automated Weaning?

- SmartCare
- Proportional Pressure Support
- Adaptive Support
- Automode
- Intellivent-ASV
- PAV
- NAVA
Automated versus non-automated weaning for reducing the duration of mechanical ventilation for critically ill adults and children: a cochrane systematic review and meta-analysis

Louise Rose1,2,3,4,5*, Marcus J Schultz6, Chris R Cardwell7, Philippe Jouvet8, Danny F McAuley9 and Bronagh Blackwood10

Results: We identified 21 eligible trials totalling 1,676 participants. Pooled data from 16 trials indicated that automated systems reduced the geometric mean weaning duration by 30% (95% confidence interval (CI) 13% to 45%), with substantial heterogeneity ($I^2 = 87\%$, $P < 0.00001$). Reduced weaning duration was found with mixed or medical ICU populations (42%, 95% CI 10% to 63%) and Smartcare/PS™ (28%, 95% CI 7% to 49%) but not with surgical populations or using other systems. Automated systems reduced ventilation duration with no heterogeneity (10%, 95% CI 3% to 16%) and ICU LOS (8%, 95% CI 0% to 15%). There was no strong evidence of effect on mortality, hospital LOS, reintubation, self-extubation and non-invasive ventilation following extubation. Automated systems reduced prolonged mechanical ventilation and tracheostomy. Overall quality of evidence was high.
What is the ‘comparator’ limb?

Who are the patients?

What is the protocol?
Protocols avoid weaning delays and missed opportunities.
Wean Earlier and Automatically with New Technology (the WEAN Study)
A Multicenter, Pilot Randomized Controlled Trial

Karen E. A. Burns¹,², Maureen O. Meade³, Martin R. Lessard⁴,⁵, Lori Hand⁶, Qi Zhou³, Sean P. Keenan⁷, and François Lellouche⁴,⁸

Am J Respir Crit Care Med Vol 187, Iss. 11, pp 1203–1211, Jun 1, 2013

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**AT A GLANCE COMMENTARY**

**Scientific Knowledge on the Subject**

This is a randomized trial to compare automated weaning with a standardized weaning protocol in a multidisciplinary population and to evaluate clinicians’ perceptions of the study weaning and sedation protocols.

**What This Study Adds to the Field**

Clinician compliance with and acceptance of the protocols were overall good. The beneficial effects of automated weaning on clinical outcomes compared with a protocol that likely represented better than usual care suggests that automated weaning may aid clinicians to recognize weaning readiness and warrants further investigation.
Is Automated Weaning Superior? It All Depends…

- Which population?
- What is your staffing and surveillance?
- How good is your implementation?
  - Algorithm
    - Inclusive of gas exchange?
    - Inclusion of non-respiratory variables?
  - Weaning protocols
- ABCDEF guidelines followed?
- Etc…
Automated Weaning
Still Incomplete

Transpulmonary Pressure Adjustment Timing
Cardiovascular Tolerance
Justification for ‘Closed Loop’ Automated Control of ‘Weaning’ Readiness

• Potential to Lower Costs
• Increased Demand for Ventilation
• Staffing Issues
• Widespread Failure to Implement Best Practice
• Need for Better Surveillance

(after R Branson)
Liberation Sequence

- Preparation
- Evaluation
- Withdrawal of Support
  - Ventilator
  - Endotracheal Tube
- Peri-Extubation Care
Inspect The Airway *Before* Extubation!

Zamanian, Marini *Crit Care Med* Jan 2006
Upper Airway Patency

- Test Cuff “Clearance” Prior to Extraction
- Use High PEEP to Break Mucus Seal
Mucus Seal—Cuff Deflation Test

20 cmH₂O PEEP
Cuff Leak?

• *Always* perform CLT prior to extubation
  – High PEEP (12-20 cmH2O) and volume assist control
  – Monitor set vs. recovered VT
• If no leak ...
  – Upright position
  – Move head in orthogonal planes
  – Steroids +/- diuretics x 12-24 hours?
Endotracheal Tube Removal

High PEEP (15 cmH₂O) for a few breaths just prior and *while* the tube is extracted

- Avoids false cuff deflation test
- Often breaks mucus seal
  - Head position
  - Tube advance or withdrawal
- Helps eliminate upper tract mucus
Tube Extraction
Sequelae of Cuff Inflation

Cuff-induced muscle tone
Compressive edema
Sustained Pharyngeal Pressure

Regional ischemia
PCV with PEEP and *Cuff Deflated*
Cuff Leak?

- **Always** perform CLT prior to extubation
  - High PEEP (12-20 cmH2O)
  - Monitor set vs. recovered VT
- **If no leak** ...
  - Upright position
  - Move head in orthogonal planes
  - Keep cuff *deflated* for 15-60 min
    - 10 cmH2O PEEP
    - 7-15 cmH2O PCV
  - Steroids +/- Diuretics x 24 hours
The Weaning Process

- Preparation
- Evaluation
- Withdrawal of Support
  - Ventilator
  - Endotracheal Tube
- *Peri*-Extubation Care
Peri-Extubation

- Aggressive secretion clearance, respiratory care, and fluid balance
- Consider nasal trumpet *pre*-extubation
- Inspect Airway prior to extubation

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- *Humidified* intermittent Bi-PAP
- Consider nasal high flow
- Nasal prongs whenever possible
Post-Extubation

Head at > 45 degrees

Consider Modafenil
Pharyngeal and Glottic Edema

Impaired Swallow
Residual Sedation
Sleep Deficit
Flow-Volume Curves Before and After Extubation
Especially helpful during sleep and early post extubation

Humidify the Airstream!
High $V_E$, Mouth Open, Increased $FiO_2$
Preferable if Secretions *and* Cough?
Humidified High Flow Nasal Cannula

- Deadspace Washout
- Expiratory Retard
- Mild CPAP
- Reflex
- Unimpeded Cough
Can We Promote Early Liberation With Veno-Venous CO₂ Removal and Oxygenation?

Pump Regulated Blood Flow
Tips or Tricks?

Show us the EVIDENCE!!
END