# Weaning from Mechanical ventilation

## Assessment and comparison of available methods

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# Introduction

**Process of abruptly or gradually withdrawing ventilatory support**

Discontinuation of mechanical ventilation → Removal of artificial Airway

# Double edged sword !!

- Unnecessary delays in this discontinuation process increase the complication rate from mechanical ventilation (eg, pneumonia, airway trauma) as well as the cost

- Premature discontinuation carries its own set of problems, including difficulty in reestablishing artificial airways and compromised gas exchange

# Double edged sword !!

- On an average 42% of the time that a medical patient spends on a mechanical ventilator is during the discontinuation process

- Up to 20% of patients experience difficulty in the process of weaning

# Reasons for ventilator dependence

- Neurologic issues
- Respiratory system muscle/load interactions
- Metabolic factors and ventilatory muscle function
- Gas exchange factors
- Cardiovascular factors
- Psychological factors

# Is the patient ready for weaning ?

- Numerous trials performed to develop criteria for success weaning, however, not useful to predict when to begin the weaning
- Physicians must rely on clinical judgment
- Consider when the reason for IPPV is stabilized and the patient is improving and haemodynamically stable
- Daily screening may reduce the duration of MV and ICU cost

# Essentials to begin weaning

- Patient parameters
  - Awake, alert and cooperative
  - Haemodynamically stable
  - RR < 30/min
  - No effect of sedation/neuromuscular blockade
  - Minimal secretions
  - Nutritional status good

*Burton GG Respir Care 1997, Caruso P 1999 Chest*
*Girault C. 1994 Monaldi Arch Chest Dis, TobinMJ. 1990 Eur Respir J,*
*Yang KL.1991 N Engl J Med*

# Essentials to begin weaning

- Ventilator parameters
  - Spontaneous TV > 5 - 8 ml/kg ,
  - VC > 10 - 15 ml/kg ,
  - PEEP requirement < 5 mm of $H_2O$
  - Static compliance > 30 ml/mm of $H_2O$
  - MV < 10 L
  - $V_D/V_T$ < 60 %

*Burton GG Respir Care 1997, Caruso P 1999 Chest*
*Girault C. 1994 Monaldi Arch Chest Dis, TobinMJ. 1990 Eur Respir J,*
*Yang KL.1991 N Engl J Med*

# Essentials to begin weaning

- Oxygenation criteria
  - $PaCO_2$ <50 mm of Hg with Normal pH
  - $PaO_2$ > 60 @ $FiO_2$ 0.4 or less
  - $SaO_2$ > 90 % @ $FiO_2$ 0.4 or less
  - $PaO_2/FiO_2$ > 200
  - $Q_S/Q_T$ < 20 %
  - $P(A\text{-}a)O_2$ < 350 mm of Hg @ $FiO_2$ of 1.0

None of the variables demonstrate more than modest accuracy in predicting weaning outcome

*Burton GG Respir Care 1997, Caruso P 1999 Chest*
*Girault C. 1994 Monaldi Arch Chest Dis, TobinMJ. 1990 Eur Respir J,*
*Yang KL.1991 N Engl J Med*

# Combined indices

- **RSBI = Respiratory frequency / Tidal volume**

- **SWI =** $$\frac{f_{mv}(PIP - PEEP)}{MIP} \times \frac{PaCO_{2\,mv}}{40}$$

- **CROP index =** $$\frac{[C_{DYN} \times MIP \times PaO_2 / PAO_2]}{f}$$

# Predicting success !!

**Rapid shallow breathing index**

- Several studies have demonstrated that the rapid shallow breathing index (f/VT) is superior to conventional parameters in predicting the outcome of weaning

*Chatila W Am J Med 1996, Jacob B Crit Care Med 1997, Krieger BP, Chest 1997*

In a recent randomized, blinded controlled trial 304 patients admitted to intensive care units were enrolled and RSBI was taken as a major weaning predictor

# Predicting success !!

The median duration for weaning time was significantly shorter in the group where the weaning predictor was not used (2.0 vs. 3.0 days, p =0 .04). There was no difference with regard to the extubation failure, in-hospital mortality rate, tracheostomy, or unplanned extubation.

*Crit Care Med 2006; 34:2530–2535*

In a recent study including 900 patients extubation failure occurred in 121 (13.4%)

# Predicting success !!

Among routinely measured clinical variables, RSBI, positive fluid balance 24 h prior to extubation, and pneumonia at the initiation of ventilation were the best predictors of extubation failure

But the threshold for RSBI was lower(>57) as compared to previously used value of >100

*Chest 2006; 130:1664–1671*

The direction and magnitude of the change from pretest to post-test probability are determined by the likelihood ratio

# Can we predict weaning success?

In a study by *Jabour* et al SWI < 9/min had 93 % prediction for a successful weaning attempt and if SWI > 11/min there was 95% probability of weaning failure

*Am Rev Respis Dis 1991;144:531-537*

A CROP index > 13 ml/breaths/min was a predictor of weaning success in a study by *Yang* et al

*N Engl J Med. 1991; 324: 1445- 1450*

*The decision to use these criteria must be individualized*

# Issues to be addressed

- Gradual vs. sudden?
- Which mode to be used for weaning?
- Are newer modes useful for weaning?
- Is protocol driven weaning better?
- Is computer directed weaning better?

# Gradual vs. sudden weaning?

- No data available
- Most trials have used sudden weaning using Spontaneous breathing trial with T-piece, PSV or CPAP
- However if a patient fails recurrent weaning attempts gradual weaning strategy is advocated

*Respir Care 2002; 47: 69-90*

# Available modes of weaning

**CONVENTIONAL MODES**

- Spontaneous breathing trials
- Pressure support ventilation
- SIMV
- SIMV + PSV

**NEWER MODES**

- Automatic tube compensation
- Adaptive support ventilation
- Auto-mode ventilation
- Airway pressure release ventilation
- Volume assured pressure support
- Proportional assist ventilation
- Non invasive positive pressure ventilation

# Spontaneous breathing trials

Two large randomized trials comparing SBT with other modalities

Esteban et al compared 2-h trials of unassisted breathing using PS of 7 cm H2O vs a T-piece

A smaller proportion of patients in the PS group (14%) failed to tolerate the weaning and to achieve extubation at the end of the 2-h trial than in the T-piece

Reintubation rates were similar

# Spontaneous breathing trials

Second study by same authors

**Compared a 30-min to a 120-min T-piece trial**

**No reported difference in the rate of re-intubation between groups patients who were randomized Shorter T-piece trial benefited from statistically significant reductions in ICU and hospital lengths of stay (2 days and 5 days shorter, respectively)**

# Spontaneous breathing trials

Various other trials – small sample size

Analysis of pooled data across two studies the number of events was so low that the 95% CIs were extremely wide
(relative risk for nonextubation in CPAP vs T-piece breathing, 1.66 [95% CI, 0.60 to 4.64]; relative risk for reintubation, 1.61 [95% CI, 0.39 to 6.59])

*Meade M Chest 2001; 120:425S–437S*

# Stepwise reduction

SIMV/PSV and T- piece trials

Five randomized controlled trials (RCTs) compared alternative methods of reducing ventilatory support in patients in whom clinicians thought that extubation was still several days away

Two studies compared multiple daily T-piece breathing; PS; and SIMV

*Esteban A. N Engl J Med 1995, Brochard L. Am J Respir Crit Care Med 1994*

# Stepwise reduction

Study design was almost similar in both the studies

In comparison of T-piece breathing to PS, the pooled results showed no difference in the duration of ventilation, the trends going in opposite directions in the two studies

The results of the trial by Esteban et al favored weaning with T-piece breathing, and those of the trial by Brochard et al favored PS

# Stepwise reduction

In the comparison of T-piece breathing to SIMV, the two trials showed similar trends in favor of T-piece in the duration of ventilation

In the comparison of PS to SIMV on the duration of weaning, both studies found trends in favor of PS, although the effect in the study by Brochard et al was much larger

# Stepwise reduction

Recent randomized prospective study including 260 patients who received mechanical ventilation for more than 48 h

Total length of additional mechanical ventilation and total length of stay at ICU - significantly shorter in patients undergoing PSV weaning

For the patients with weaning difficulties and APACHE II score>20 on admission, PSV was the superior

*CMJ 2004;45;162-166*

# Stepwise reduction

Another study- 19 patients randomized to SIMV with PS vs SIMV without PS

The duration of the weaning process was approximately 1 day shorter in the group that received PS, with the lower boundary of the 95% CI being approximately 7 h

Two patients in the SIMV group, and none in the group that also received PS, required reintubation

*Jounieaux V. Chest 1994*

# Discussion

**Poorer outcome with SIMV in general !!**

Designed to provide respiratory muscle rest during mandatory breaths and exercise during intervening breaths

Main reason for poor outcomes with this mode is that actually respiratory muscles ***never rest***

# Discussion

**Huge discrepancy in results of various trials**

Esteban and colleagues found that 22% of 246 patients failed a T-piece weaning trial, and of the 192 who were extubated, 19% required reintubation. In contrast, Jones and coworkers reported that only 4% of 52 patients undergoing weaning with T-piece breathing were not extubated, and of those extubated, only 4% of 50 patients required reintubation

These discrepancies suggest that investigators are using quite different criteria when judging whether a patient is ready for a trial of spontaneous breathing and for judging when the trial is a success and extubation is appropriate

# Discussion

The mean duration of weaning in the T-piece breathing group in the trial by Brochard et al was 8.5 days, and in the study by Esteban et al, 3 days

Major focus of judgment may be issues of patient selection and the judgment as to when the weaning process begins

*Esteban A. N Engl J Med 1995, Brochard L. Am J Respir Crit Care Med 1994*

# Discussion

Results of two studies of weaning in 48 h provide further evidence that SIMV may be less advantageous than other methods of decreasing mechanical ventilatory support.
However, these trials compared particular SIMV weaning regimens.
Other weaning regimens using SIMV may produce different results.

Jounieaux et al of SIMV and PS vs SIMV suggests the superiority of a regimen that includes PS
Study provides very little information about the effects on outcomes of nonextubation or reintubation because of small sample size and low number of events

Jounieaux V. Chest 1994

# Discussion

**Systemic review  comparing various popular weaning modes**

A superior weaning technique among the three most popular modes, T-piece, pressure support ventilation, or synchronized intermittent mandatory ventilation cannot be identified

SIMV may lead to a longer duration of the weaning process than  either T-piece or PSV

The most effective mode of ventilation for weaning still needs to be determined and more work is required in this area.

# Newer modes

**Automode**

Available on Siemens Servo ventilators
Combines volume support (VS) and pressure regulated volume control (PRVC) into one mode
If patient paralyzed or apneic-Pressure limited time cycled breaths, with variable pressure to achieve desired tidal volume

# Newer modes

After two spontaneously triggered breaths, the ventilator mode changes automatically from mandatory to spontaneous ventilation - If the patient does not continue to trigger the ventilator mode changes again automatically from spontaneous to mandatory

Time to extubation was 2 h shorter in patients assigned to automode ventilation (n=10) compared to patients assigned to conventional ventilation (n=10)

*Eur J Cardiothorac Surg 2006; 29: 957-963*

# Newer modes

**Automatic Tube Compensation**

- Continuous calculation of $P_{trach}$ using
  - Known resistive component of ET tube
  - Measurement of flow
- Compensation for tube resistance by closed loop control of calculated $P_{trach}$

Results in decrease in work of inspiration

Reduction of $R_{exp}$ and PEEPi

# Newer modes

Comparision of Tp, PSV and or ATC

Among all 90 patients (30 per group) no significant differences between the modes was observed.
Twelve patients failed the initial weaning trial.
Half of the patients who appeared to fail the spontaneous breathing trial on the T-tube, PSV, or both, were successfully extubated after a succeeding trial with ATC

ATC can be used as an alternative mode during the final phase of weaning from mechanical ventilation

*Haberthür C. Acta Anaesthesiol Scand 2002; 46: 973–979*

# Newer modes

In a recent study, more patients in the ATC group underwent successful extubation (ATC, 42/51, vs. CPAP, 31/48; $p < 0.04$)

The absolute risk reduction in favor of ATC of 17.7% (95% confidence interval, 0.67-35%) and a NNT of six

*Crit Care Med 2006;34:682-686*

# Newer modes

## Airway Pressure Release Ventilation (BIPAP/VPAP)

Partial support mode
Somewhat similar to PCIRV
Interspersed long (moderately high) airway pressure and short deflation periods - unassisted breathing during both periods
Progressive lower $P_{peak}$

## Proportional Assist Ventilation

Adjusts airway pressure in proportion to patient effort
Unlike other modes, amount of support changes with level of patient effort
Better patient-ventilator synchrony

# Newer modes

Positive feedback controller in which respiratory elastance and resistance are the feedback signal – Typically PAV must be set to ~ 80% of patient's elastance and resistance

Estimation of respiratory resistance and elastance

Temporal fluctuation in these values(RUNAWAY)

Limited physician experience

# Newer modes

**Adaptive support ventilation**

Dual control breath to breath time cycled and flow cycled breaths and allows the ventilator to choose the initial ventilator settings based on clinicians input of IBW and percent minute volume0

Most sophisticated of the closed loop techniques available

# Newer modes

**<u>Volume Support or Variable pressure support</u>**

All breaths are pressure supported
Closed loop control, with minute volume as target
Breath-to-breath adjustment of pressure support level to achieve set minute volume

**Benefits**
Automatic weaning of pressure limit when patient effort or lung compliance improves
Guaranteed minute ventilation

# Newer modes

**Disadvantages**

Automatic increase in pressure level may worsen auto-PEEP in patients with airflow obstruction

In tachypneic patients, as net ventilatory demand increases, the ventilator support paradoxically decreases

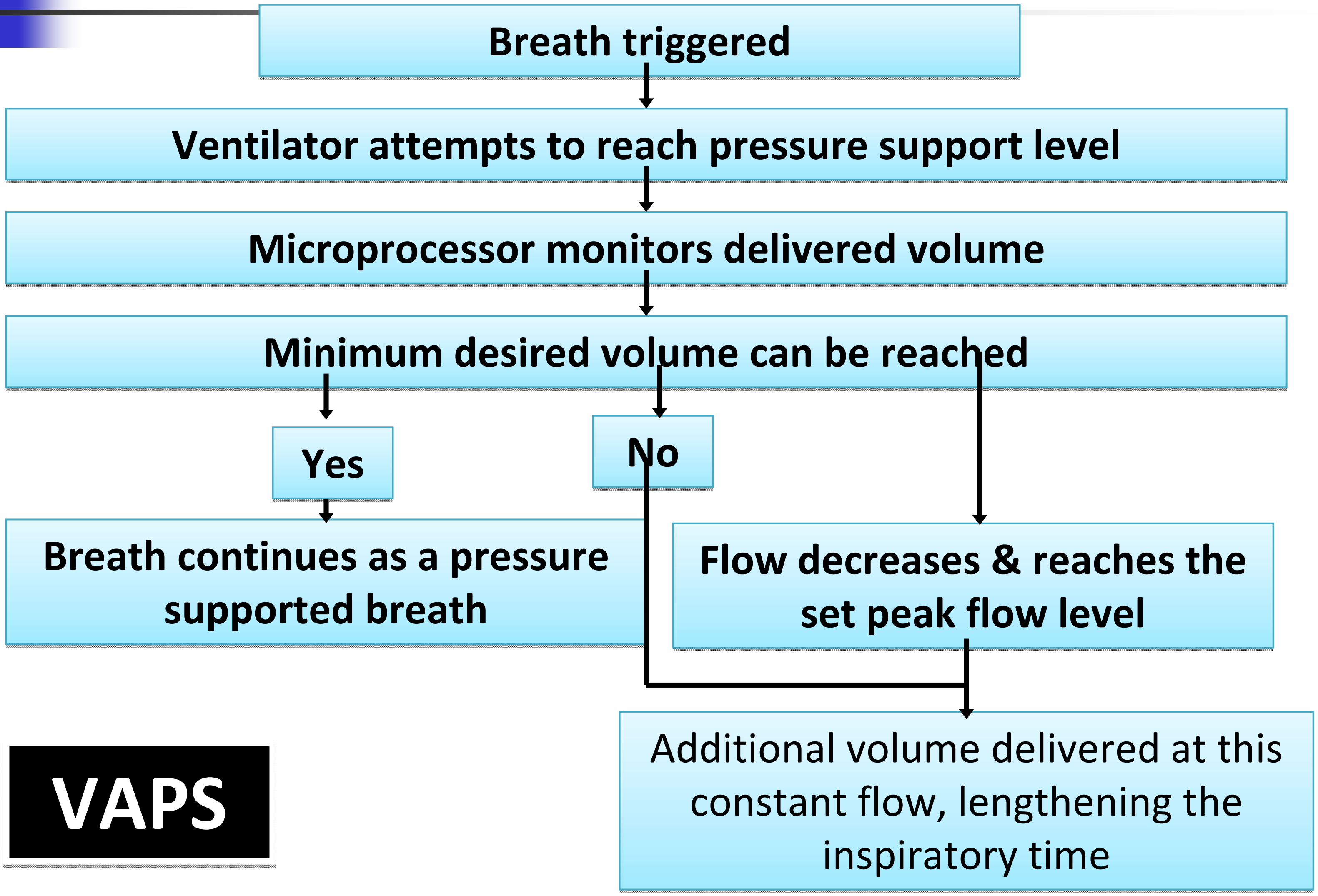
# Newer modes

Pressure regulated volume control, APV or Autoflow

Not exactly a weaning mode. Similar to volume support but uses pressure limit and is a pressure control mode

Maintains minimum peak pressure and provides constant set tidal volume and automatic weaning as the patient improves

# Newer modes




**VAPS**

# NIPPV for Weaning

In this method any patient tolerating SBT is extubated and put on non invasive ventilation

All the studies have used mainly patients with chronic respiratory failure especially COPD and hence should only be used for this subgroup of patients

In a recent meta anlysis the duration of ICU stay, duration of hospitalization Occurrence of pneumonia and moratality decreased with the use of NIPPV for weaning

# Protocol guided weaning

Has been compared to physician directed weaning in various trials
But data sparse and conflicting

Many of the studies have shown better outcomes with protocol guided weaning

*Crit Care Med 1997;25:567-574 ,Arch Surg 1998;133:483-488*
*Chest 2000; 118:459–467, J Trauma 2004;56:943-951, J Intensive Care Med. 2004 Sep-Oct;19(5):274-84. N Engl J Med 1996 Dec 19;335(25):1864-9,*
*Am J Crit Care 2003 Sep;12(5):454-60,*
*Respir Care 2001 Aug;46(8):772-82, 1995 Mar;40(3):219-24*

# Protocol guided weaning

Proposed benefit of protocolized weaning are decrease in ventilation time and decreased cost

Also lesser number of staff recruitment has been seen in this subgroup

Few studies have also demonstrated negative results in terms of longer weaning times

*Am J Respir Crit Care Med 2004;169:673-678*
*Anaesthesia 2006;61:1079-1086,*
*Arch Surg. 2002 Nov;137;11:1223-7*

# Protocol guided weaning

Results of protocol guided weaning strategies are largely affected by the prevailing practices in a particular ICU

And different weaning protocols will result in different results so results of existing studies cannot be extrapolated or generalized

Moreover in well equipped and staffed ICU protocolized weaning may not be required at all

# Computer driven weaning

In a two-center, prospective, open, clinical, pilot study in medical ICUs, 42 consecutive mechanically ventilated patients were evaluated

Weaning was successful in 25 patients and failed in 7; unplanned extubation occurred in 1 patient. Time on computer driven system (CDS) ventilation was 3 ± 3 days The CDS detected weaning readiness earlier than the intensivists in 17 patients, and intensivists earlier than the CDS in 4; in 11 patients detection times coincided

*Bouadma L. Intensive Care Med 2005 ;31:1446–1450*

# Computer driven weaning

144 patients were enrolled before weaning initiation - randomly allocated to computer-driven weaning (CDW, n=74) or to physician-controlled weaning (PCW, n=70)

Weaning duration was reduced in the CDW group from a median of 5 to 3 d (p = 0.01) and total duration of mechanical ventilation from 12 to 7.5 d (p = 0.003). Reintubation rate did not differ (23 vs. 16%, p = 0.40). CDW also decreased median ICU stay duration from 15.5 to 12 d (p = 0.02) and caused no adverse events

*Lellouche F.Am J Respir Crit Care Med 2006;174:894-900*

# Miscellaneous interventions

- Fluid balance
- Intensive euglycemia
- Composition of enteral nutrition
- Role of glucocorticoids
- Growth hormone
- Role of tracheostomy
- Oxymetry  and capnography
- Relaxation biofeedback
- Acupuncture

# Role of tracheostomy

Improved patient comfort

More effective airway suctioning

Decreased airway resistance

Enhanced patient mobility

Increased opportunities for articulated speech

Ability to eat orally, a more secure airway

Accelerated weaning from mechanical ventilation

Ability to transfer ventilator-dependent patients from ICU

# Role of tracheostomy

Early tracheotomy performed
within the first 7 days of mechanical ventilation
decreases the duration of mechanical ventilation

*Rodriguez JL. Surgery 1990; 108:655–659*

Tracheotomy reduces the mechanical workload, work of breathing , and the mouth occlusion pressure at 0.1 s after inspiratory effort of ventilator dependent patients

*Diehl JL. Am J Respir Crit Care Med 1999; 159:383–388,*
*Davis K Jr. Arch Surg 1999; 134:59–62*

# Role of tracheostomy

Early and late tracheostomy has been compared in various studies  But have shown conflicting results with reference to duration of ventilation, hospital or ICU stay

Incidence of VAP has also been reported to be lower in the tracheostoimsed in some studies but  not in others


*Lesnik I. Am Surg 1992; 58:346–349*
*Blot F. Support Care Cancer 1995; 3:291–296*
*Koh WY. Anaesth Intensive Care 1997; 25:365–368*
*Dunham MC. Trauma 1984; 24:120–124*
*El-Naggar M. Anesth Analg 1976; 55:195–201*
*Sugerman HJ. J Trauma 1997; 43:741–747*

# Concluisons

Selection of a particular mode should be determined by availability and physician experience

Once daily T-piece weaning or PSV superior to SIMV

Early extubation with back up ventilation of NIPPV is useful especially in COPD

Role of newer modes unclear – require more studies

Protocol and computer directed protocols may be helpful in open and less staffed ICUs

# A reasonable strategy !