End tidal co2 monitoring during mechanical ventilation of critically ill Pediatric patients us a marker of weaning success

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INTRODUCTION

Weaning from Mechanical ventilation (MV) is a key component in the care of critically ill and injured patients. Almost half the time patients spend on mechanical ventilation is devoted to weaning . Delays in weaning the patient from MV increase the number of complications and may lead to increased expenditure. Consequently, weaning constitutes a major challenge for the intensive care staff **(Plost and Nelson, 2007).** Prolonged mechanical ventilation is associated with significant morbidity and mortality. Therefore, weaning should be considered as early as possible in the course of mechanical ventilation **(Kress et al., 2000).**

So far , no reliable predictor of weaning failure has been identified while the patient is still under mechanical ventilation **(Jurban and Tobin, 1997).**

Carbon analysis of CO2 is important to the measurement & under standing of intra pulmonary gas mixing , ventilation perfusion relation ships. A time based capnography provided qualitative information on the wave forms associated with mechanical ventilation& quantitative estimation of partial pressure of $ETCO_2$ .Capnogram is the ECG of respiration. Just as the electrocardiogram is one indicator of cardiac health, the capnogram is an important adjunct to assessing respiratory function **(Smalhout,1997).**

AIM OF WORK

To evaluate End Tidal CO2 monitoring as a non invasive tool to assess the weaning success of mechanically ventilated pediatric patients in PICU Ain Shams University.

Weaning From Mechanical Ventilator

Introduction

Weaning from Mechanical ventilation (MV) is a key component in the care of critically ill and injured patients. Almost half the time patients spend on mechanical ventilation is devoted to weaning. Delays in weaning the patient from MV increase the number of complications and may lead to increased expenditure. Consequently, weaning constitutes a major challenge for the intensive care staff. It is important to wean the patient from MV as expeditiously as possible. Several studies indicate that the implementation of nurse-led, protocol-directed weaning reduces the amount of time spent on MV, the length of ICU stay, and associated costs **(Plost and Nelson; 2007).**

Weaning process

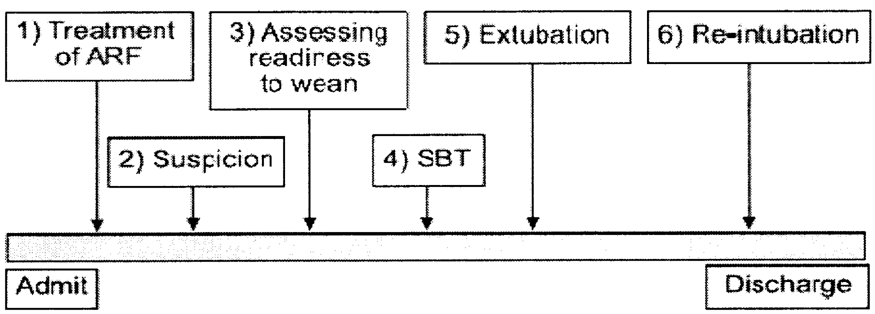

FIGURE 1. Schematic representation of the different stages occurring in a mechanically ventilated patient. ARF: acute respiratory failure; SBT: spontaneous breathing test.

As illustrated in figure 1, **(Tobin et al; 2005)** a series of stages in the process of care, from intubation and initiation of mechanical ventilation through initiation of the weaning effort to the ultimate liberation from mechanical ventilation and successful extubation. These six stages are defined in table 1 and are as follows:

1) Treatment of acute respiratory failure (ARF)
2) Suspicion that weaning may be possible
3) Assessment of readiness to wean
4) Spontaneous breathing trial (SBT)
5) Extubation ; and
6) Possibly reintubation.

Table (1) Definition of the different stages, from initiation to mechanical ventilation to weaning

stages	***Definitions***
Treatment of ARF	Period of care & resolution of the disorder that caused respiratory failure & prompted mechanical ventilation
Suspicion	The point at which the clinician suspects the patient may be ready to begin the weaning process
Assessing readiness to wean	Daily testing of physiological measures of readiness for weaning (MP,fR/VT) to determine probability of weaning success
Spontaneous breathing trial	Assessment of the patient's ability to breathe spontaneously
Extubation	Removal of the endotracheal tube
Reintubation	Replacement of the endotracheal tube for patients who areunable to sustain spontaneous ventilation

ARF: acute respiratory failure, MIP: maximal inspiratory pressure,
fR/VT: respiratory frequency to tidal volume ratio (rapid shallow breathing index)

It is important to recognize that delay in reaching stage 2, the suspicion that weaning may be possible, and beginning stage 3, assessing readiness to wean, is a common cause of delayed weaning. Stage 2 begins when the clinician first thinks there is a reasonable probability of weaning success. Stage 3 begins when the clinician actually initiates a process of daily tests of readiness to wean in order to confirm this suspicion. Stage 3 ends when the results of the daily test cause a reassessment of the probability to a high enough level to justify an SBT. The weaning process begins with the first SBT, defined as a T-tube trial or a low-level pressure support. Although life saving, mechanical ventilation is associated with numerous complications .These include Ventilator- associated pneumonia (VAP), cardiovascular compromise, barotraumas, and ventilator-induced lung injury. Recent data suggest that controlled mechanical ventilation can cause dysfunction of the diaphragm, decreasing its force-generating capacity, a condition referred to as ventilator-induced diaphragmatic dysfunction (VIDD). The decrease in diaphragmatic force that occurs during controlled mechanical ventilation is attenuated during assisted modes of ventilation. Whether the decrease in diaphragmatic contractility observed during controlled ventilation contributes to failure to wean from the ventilator is difficult to ascertain **(Vassilakopoulos and Petrof; 2004).**

Classification of patients:

A new classification of patients into three groups is proposed during the International Consensus Conference, according to the difficulty and length of the weaning process (table 2) **(Brochard ;2005).**

Table 2	Classification of patients according to the weaning process
Group	**Definition**
Simple Weaning	Patients who proceed from initiation of weaning to successful extubation on the first attempt without difficulty
Difficult weaning	Patients who fail initial weaning and require up to three SBT or as long as 7 days from the first SBT to achieve successful weaning
Prolonged weaning	Patients who fail at least three weaning attempt or require>7 days of weaning after the first SBT
SBT=spontaneous breathing trial	

The simple weaning group includes patients who successfully pass the initial SBT and are successfully extubated on the first attempt. This group, named group 1, represents 69% of weaning patients. Prognosis in this group is good, with an ICU mortality of 5% and an in hospital mortality of 12%. The remaining patients (31%) represent groups 2 and 3. In this population, ICU mortality is, 25% **(Esteban et al;1999).** Group 2, difficult weaning, includes patients who require up to three SBT or as long as 7 days from the first SBT to achieve successful weaning. Group 3, prolonged weaning, includes patients who require more than three SBT or 7 days of weaning after the first SBT. the 75th percentile for duration of weaning for all patients, for those with COPD and those with acute respiratory distress syndrome (ARDS) was 4, 5 and 6 days, respectively **(Esteban et al;1995)** about half of the patients who failed initial SBT (group 2) still required mechanical ventilation at day 7. Therefore, the current authors estimate that, 15% of patients would be in the prolonged weaning group (group3). **(Brochard et al; 1994).**

Timing for the initiation of weaning

Recognizing and treating the processes that caused the patient to go on the ventilator is the first goal in liberating him or her from MV. The complete resolution of the inciting event that led to respiratory failure does not need to be accomplished to start the process of weaning. Partial resolution of the cause of respiratory failure may be enough to be able to discontinue MV. There are many reasons to attempt to get patients of MV as so on as possible. Common side effects of MV are hemodynamic disturbances, need for sedation, tracheal damage, ventilator-associated pneumonia (VAP), increased incidence of GI stress ulcers/bleeding, skin break down and decubiti , muscle wasting and weakness, and barotrauma. It is imperative to attempt to decrease the occurrence of these iatrogenic problems (eg, reducing plateau airway pressure, reducing tidal volumes, and semi-recumbent position 30 to 45 degrees upright) and reduce the time of exposure by reducing the length of MV. Not only have studies show that about 40% of the time during MV is devoted to weaning, but they also have shown that the most common approach to weaning is a progressive reduction of ventilatory support Others have noted that most patients do not need progressive withdrawal of MV. Evidenced-based practice now supports early attempts at weaning in a protocol-driven fashion Successful extubation in the shortest possible time is associated with improved patient outcomes and minimized cost associated with MV **(Anzueto et al;2000).**

Key elements to optimize weaning:

a-Determine cause of ventilatory dependency.
b-Rectify correctible problems:
 -Pulmonary gas exchange.
 -Fluid balance.
 -Mental status.
 -Acid- base status.
 -Electrolyte disturbance.
c-Consider psychological factors.
d-Optimize posture.
e-Provide ambulation.

Assessing readiness to wean

Prolonged mechanical ventilation is associated with significant morbidity and mortality. Therefore, weaning should be considered as early as possible in the course of mechanical ventilation. The process of initial weaning from the ventilator involves a two-step strategy. It begins with an assessment regarding readiness for weaning, which is then followed by SBT as a diagnostic test to determine the likelihood of successful extubation. In fact, for the majority of patients, the entire weaning process simply involves confirmation that the patient is ready for extubation. Patients who meet the criteria reported in (table 3) should be considered as being ready to wean from mechanical ventilation. Failing to extubate patients who can in fact be successfully weaned is more injurious than a failed SBT. Since many patients who do not meet all the criteria in (table 3) are able to wean successfully from mechanical ventilation.

Table 3	Consideration for assessing readiness to wean
Clinical assessment	Adequate cough Absence of excessive trachea-bronchial secretion Resolution of disease acute phase for which the patient was intubated
Objective measurements	Clinical stability Stable cardiovascular status (i.e:HR≤140 beats/min, systolic Bp 90/160, no or minimal vasopressors) Stable metabolic status Adequate oxygenation SaO_2> 90% on ≤ FiO_2 o.4(or PaO_2/FiO_2 ≥ 150 mmHg) PEEP ≤ 8 cmH_2O Adequate pulmonary function RR ≤ 35 breath/min MIP ≤ 20-25 cmH_2O VT > 5ml/Kg VC > 10ml/kg RR / VT < 105 breathes/min/L No significant respiratory acidosis Adequate mentation No sedation or adequate mentation on sedation (or stable neurogenic patient)

HR: heart rate ; BP: blood pressure ; Sao_2 : arterial oxygen saturation ; FiO_2 : inspiratory oxygen fraction ; PaO_2 : arterial oxygen tension ; PEEP : positive end -expiratory pressure ; RR : respiratory rate ; MIP : maximal inspiratory pressure ; VT: tidal volume ; VC: vital capacity **(Kress et al;2000).**

These criteria should be viewed as considerations for probable weaning rather than as strict criteria that must all be met simultaneously. The initial assessment of the readiness for discontinuation of mechanical ventilation support often involves calculation of the rapid shallow breathing index (RSBI) . In general , patients should be considered for an RSBI calculation and subsequent SBT earlier rather than later, since physicians frequently underestimate the ability of patients to be successfully weaned. For many patients, discontinuation of sedation is a critical step that can be achieved by either daily interruption of sedation or continuous titration of sedation to a level that allows the patient to be adequately responsive **(Kress et al ;2000).**

An SBT should be considered as soon as possible once the patient meets the criteria in (table 3); again, these criteria are to be taken as considerations rather than as rigid requirements. An initial assessment of the likelihood of a successful SBT is appropriate in order to avoid trials in patients with a high probability of failure. However, the predictive value of indices that attempt to predict successful SBT may be low in clinical practice. But it must be considered that pre test probability of successful weaning, upon which predictive value of indices is based, may be very high because of the late measure of these indices in a majority of patients' course. The most commonly used test is calculation of the RSBI (respiratory frequency (fR) /VT). A value <100–105 breaths/min/L predicts a successful SBT with a reported sensitivity of 0.97 and specificity of 0.65 **(Yang and Tobin; 2005).**

Criteria for passing SBT include respiratory pattern, adequate gas exchange, haemodynamic stability and subject comfort. Six large studies **(Farias et al ;2001)** demonstrated that only 13% of patients who successfully passed the SBT and were extubated required reintubation. In patients who do not receive an SBT and are extubated, the failure rate is 40%.

Patients who successfully pass the SBT should be extubated if neurological status, excessive secretions and airway obstruction are not issues. Although depressed mentation is frequently considered a contra - indication to extubation demonstrated a low reintubation rate (9%) in stable brain-injured patients with low Glasgow coma score did not predict extubation failure. Poor cough strength and excessive endotracheal secretions were more common in patients who failed extubation following a successful SBT. In patients with neuromuscular ventilatory failure, a peak cough flow of 160 L/min correlated with extubation success **(Khamiees; 2001).**

When upper airway obstruction due to oedema is a potential concern, a positive leak test (air leaks around the endotracheal tube after deflation of the cuff) is adequate before proceeding with extubation **(Jaber et al ;2003).**

When patients fail an initial SBT, the criteria of which are reported in table 4, the clinician should review possible reversible etiologies for failure .The SBT should be repeated frequently (daily) in order to determine the earliest time at which the patient can be successfully extubated. Although respiratory muscle fatigue has been considered to be a major reason for continuing failure to wean from mechanical ventilation, recent data demonstrate that weaning failure is not accompanied by low-frequency fatigue of the diaphragm **(Laghi et al;2003).**

Table (4)	Failure criteria of spontaneous breathing trials
Clinical assessment & subjective indices	Agitation & anxiety Depressed mental status Diaphoresis Cyanosis Evidence of increasing effort Increased accessory muscle activity Facial signs of distress Dyspnoea
Objective measurements	PaO_2 ≤50-60 mmHg on FIO_2 ≥0.5 or SaO_2< 90% $PaCO_2$>50 mmHg or an increase in $PaCO_2$ >8 mmHg PH<7.32 or a decrease in PH ≥0.07 PH units fR/VT>105 breaths/min/L fR>35 breaths/min/L or increased by ≥50% fC>140 breaths/min/L or increased by ≥20% systolic BP>180 mmHg or increased by ≥20% systolic BP<90 mmHg cardiac arrhythmias

PaO_2 : arterial oxygen tension , FIO2 : inspiratory oxygen fraction , SaO_2 : arterial oxygen saturation , $PaCO_2$: arterial carbon dioxide tension , fR : respiratory frequency , VT : tidal volume , fC : cardiac frequency , BP : blood pressure , 1mmHg= 0.133 kpa

ROLE FOR DIFFERENT VENTILATOR MODES IN MORE DIFFICULT WEANING:

In patients requiring mechanical ventilation, weaning failure is relatively common When initial attempts at spontaneous breathing fail to achieve the goal of liberation from mechanical ventilation, clinicians must choose appropriate mode(s) of ventilatory support which:

1) maintain a favourable balance between respiratory system capacity and load.
2) attempt to avoid diaphragm muscle atrophy.
3) aid in the weaning process. **(Cooper et al ; 2004).**

Noninvasive ventilation

In weaning, NIV has been studied for three different indications, which should be strictly separated;

- First, NIV has been used as an alternative weaning modality for patients who are intolerant of the initial weaning trial.
- Secondly, NIV has been used as a treatment option for patients who have been extubated but developed ARF within 48 h.
- Thirdly, NIV has been used as a prophylactic measure after extubation for patients who are at high risk for reintubation but who did not develop ARF **(Ferrer et al ;2003).**

Continuous positive airway pressure:

CPAP applied during spontaneous breathing in patients with acute respiratory insufficiency reduces mean intrathoracic pressure, has beneficial effects on right and left ventricular performance , improves oxygenation and reduces the Work of breathing. From a physiological point of view, additional application of PEEP either alone or with PSV seems logical for weaning. Use of CPAP during weaning may be helpful to prevent immediate postextubation hypoxaemia; however, compared to T-piece trials no clear improvement in outcomes has been observed. Lastly, CPAP has been used for prophylaxis against post-operative extubation failure observed, in a multicentre randomised controlled trial, that CPAP compared to oxygen supplementation substantially reduced the reintubation rate **(Squadrone et al;2005).**

Automatic tube compensation:

The use of ATC, a ventilatory method aimed at compensating for the nonlinear pressure drop across the endotracheal tube during spontaneous breathing, is at least as successful as the use of simple T-tube or low-level PS for weaning from mechanical ventilation . If an SBT fails because of a particularly narrow endotracheal tube, ATC may be beneficial **(Haberthur et al ;2002).**

Proportional assist ventilation:

The physiological response to proportional assist ventilation (PAV) in comparison to CPAP, there was no substantial difference in oxygenation, pressure time product and other physiological variables. Only when CPAP was combined with PAV was a more substantial change in these parameters notable . PAV is available with some respirators but its application is sometimes regarded as difficult and has not been investigated thoroughly in weaning trials **(Delaere et al ;2005).**

Servo-controlled ventilation:

Rapid adaptation of the ventilatory support to the changing situations of a patient is one of the major factors determining the length of the weaning process. However, ICU staff resources are often too limited to allow immediate response. Automatic ventilatory modes provide a tool to