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PULMONARY REHABILITATION

INTRODUCTION

Management of impairment, disability and handicap arising from a disease is the main aim of rehabilitation. American Thoracic Society (ATS) has defined pulmonary rehabilitation as "an evidence-based, multidisciplinary and comprehensive intervention for patients with chronic respiratory diseases who are symptomatic and often have decreased daily life activities. Integrated into the individualized treatment of the patient, pulmonary rehabilitation is designed to reduce symptoms, optimize functional status, increase participation, and reduce health care costs through stabilizing or reversing systemic manifestations of the disease."

Pulmonary rehabilitation programs involve patient assessment, exercise training, education, nutritional intervention, and psychosocial support with an aim to increase exercise tolerance and reduce dyspnea, increase muscle strength and endurance (peripheral and respiratory), improve health related quality of life, increase independence in daily functioning, increase knowledge of lung condition and promote self management and promote long term commitment to exercise. Most of the current evidence is from studies conducted in patients with chronic obstructive pulmonary disease (COPD).

PATIENT ASSESSMENT

Patients should be assessed for disease severity, severity of symptoms, quality of life and should undergo pulmonary function tests, cardiopulmonary exercise test and psychosocial assessment. Gains can be achieved from pulmonary rehabilitation regardless of age, sex, lung function, or smoking status and patients in all stages of COPD benefit from rehabilitation programmes. Patients with severe orthopedic or neurological disorders limiting their mobility, severe pulmonary arterial hypertension, exercise induced syncope, unstable angina or recent MI, refractory fatigue, inability to learn, psychiatric instability and disruptive behavior are excluded from rehabilitation programme.

EXERCISE TRAINING

Exercise training has been shown in studies to correct various pathological abnormalities like loss of muscle mass and decrease in type 1 muscle fibers. Better myocyte cross section area, their apposition with capillaries and increased oxidative enzymatic action is seen after exercise training.

A well structured exercise training programme should provide a minimum of 20 sessions at least three times per week. Twice weekly supervised plus one unsupervised home session may also be acceptable. Once weekly sessions are believed to be insufficient. Each session should last at least 30 minutes. High-intensity exercise (>60% of maximal work rate) produces greater physiologic benefit and should be encouraged. However, both upper and lower extremity training should be utilized. Respiratory muscle training could be considered as adjunctive therapy,

primarily in patients with suspected or proven respiratory muscle weakness. Lower extremity exercises like treadmill and stationary bicycle ergometer as well as arm (upper extremity) exercises like lifting weights and arm cycle ergometer are recommended.

Lower limb exercise training increases work capability as assessed by incremental treadmill protocol, 6 minute walking distance and 12 minute walking distance. Most of this is accounted by 40 to 100% increase in ability to maintain peak exercise (endurance) although there is no increase in peak work rate. There occurs due to an increase in aerobic capacity of muscle and oxygen consumed for any given exercise is much lesser after exercise training. Symptomatic improvement in dyspnea (assessed by Borg dyspnea scale) is seen.

Achievements of exercise training are proportional to the intensity of exercise. A target exercise intensity corresponds to at least 60% of the maximum attained power output or VO_2 peak in a preliminary progressive maximal exercise test. Alternatively, 60% of the maximal walking speed achieved on the shuttle walk test could be used.

Arm exercise has the potential to improve arm exercise performance by decreasing ventilatory demand during arm work, and by improving arm endurance. Arm training improves the ventilatory contribution of those muscles by increasing shoulder girdle muscle strength.

Respiratory muscle training could be considered as adjunctive therapy, primarily in patients with suspected or proven respiratory muscle weakness. Adequate training loads [an intensity of at least 30% of maximal inspiratory pressure ($MIP/P_{i_{max}}$)] had showed improvements in respiratory muscle strength and endurance. Exercise could be either resistive or threshold inspiratory muscle training.

Optimal bronchodilator therapy should be given prior to exercise training to enhance performance. It is reasonable to recommend supplementary oxygen to those showing significant hypoxia [arterial oxygen saturation (SaO_2) < 90%] during exercise. Neuromuscular Electrical Stimulation (NMES) may be an adjunctive therapy for patients with severe chronic respiratory disease who are bed bound or suffering from extreme skeletal muscle weakness.

Studies done in asthmatic patients have shown a similar increase in exercise capacity, in addition to a reduction in the requirement for corticosteroids as well as improvement in the quality of life. As of now there exists no unequivocal evidence for rehabilitation in restrictive lung diseases, but ATS recommends it in patients who are motivated.

BODY COMPOSITION ABNORMALITIES AND INTERVENTIONS

One-third of outpatients and up to two thirds of those

referred for pulmonary rehabilitation are under weight [body mass index (BMI) < 21 kg/m²]. Underweight patients with COPD have significantly greater impairment in health related quality of life (HRQOL) than those with normal weight. In COPD, there is an association between underweight status and increased mortality, independent of the degree of airflow obstruction. Low fat free mass (FFM) [<16 kg/m² for men and <15 kg/m² for women] has a negative impact on over all quality of life even in the presence of normal BMI.

Nutritional interventions constitute providing energy dense foods, well distributed during the day. There exists no evidence to support high fat diet use. Although hormonal interventions with growth hormone and testosterone have shown to increase body weight and FFM, their efficacy in increasing exercise capacity has not been shown in studies.

PSYCHOLOGICAL CONSIDERATIONS

The approximate prevalence of symptoms of depression in moderate to severe COPD is about 45%. Sub-threshold depression (clinically relevant depression that does not fit operational criteria) is seen in 25% of elderly patients with COPD. Screening for anxiety and depression should be part of the initial assessment. Mild or moderate levels of anxiety or depression related to the disease process may improve with pulmonary rehabilitation. Patients with significant psychiatric disease should be referred for appropriate professional care. Antidepressants and anxiolytics appear not to have additional general value.

SELF MANAGEMENT EDUCATION

Education programmes should involve the patient, his/her family members, primary care physicians and other health care providers. Various aspects of education include:

- normal lung function and pathophysiology of lung disease
- irritant avoidance, including smoking cessation
- proper use of medications, including oxygen
- benefits of exercise and maintaining physical activities
- energy conservation and work simplification techniques
- eating right
- bronchial hygiene techniques
- breathing strategies
- prevention and early treatment of respiratory exacerbations
- indications for calling the health care provider
- coping with chronic lung disease and end-of-life planning

- anxiety and panic control, including relaxation techniques and stress management

Various bronchial hygiene techniques such as postural drainage, percussion and vibration, directed cough, forced expiratory technique (huff cough), active cycle of breathing, autogenic drainage and positive expiratory pressure can be considered for patients with copious sputum production. It has been shown to be of benefit in clearance of secretions in cases of cystic fibrosis, but has no long term effect on pulmonary functions.

OUTCOME ASSESSMENT

A well structured rehabilitation programme should include outcome assessment to evaluate the impact of programme on the patient. The following outcome measures are suggested:

Control of symptoms of cough and fatigue

- Real time evaluation: VAS & Borg dyspnea scale
- Recall of symptoms

Performance evaluation

- Ability to do ADL (Activities of Daily Living)
- Directly observed or self reported

Exercise tolerance

- 6 minute walking test
- Cardiopulmonary exercise testing

Quality of life

- Chronic respiratory disease questionnaire
- St Georges's respiratory questionnaire
- SF- 36 (Short Form - 36)

LONG TERM IMPACT OF REHABILITATION PROGRAMME

Rehabilitation programmes have been shown to decrease the utilization of health care services, number of exacerbations and length of hospital stay when admitted.

Although there may be no change in the number of hospital admissions, fewer primary care home visits have been seen. Benefits of rehabilitation (exercise tolerance, dyspnea, HRQOL) are evident up to 1 year and may last longer. Current guidelines do not comment on maintenance and repeat rehabilitation programmes.

In summary, a well structured and planned rehabilitation programme consisting of exercise training, nutritional and psychological interventions as well as self management education in a properly selected patient would bear benefits in long term patient management. Symptomatic improvement, better quality of life and lesser utilization of health care facilities warrant rehabilitation programmes for chronic respiratory diseases, particularly COPD.

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WEANING FROM MECHANICAL VENTILATION

Weaning is a process of abruptly or gradually withdrawing ventilatory support which includes discontinuation of mechanical ventilation (MV) and removal of artificial airway if any. Weaning from MV can be a double edged sword. Unnecessary delays in this discontinuation process increase the complication rate from MV (e.g. pneumonia, airway trauma) as well as the cost of therapy. Premature discontinuation carries its own set of problems, including difficulty in reestablishing artificial airways and compromised gas exchange. On an average, 42% of the time that a

medical patient spends on a mechanical ventilator is during the discontinuation process and up to 20% of patients experience difficulty in the process of weaning.

Ventilator dependence is the major impediment in the process of weaning and there are several reasons for ventilator dependence like

1. Neurologic issues
2. Respiratory system muscle/load interactions
3. Metabolic factors and ventilatory muscle function

4. Gas exchange factors
5. Cardiovascular factors
6. Psychological factors

In the process of weaning the first and foremost thing to be considered is that whether the patient is ready for weaning or not. Although numerous trials have been performed in the past in an attempt to develop criteria for success weaning, they have not been successful in predicting as to when weaning should be initiated. Hence, physicians must rely on clinical judgment and contemplate weaning when the reason for MV is stabilized and the patient is improving and is haemodynamically stable. Daily screening may reduce the duration of MV and Intensive Care Unit (ICU) cost. Multiple clinical and physiological criteria to assess the readiness to start weaning in a patient on MV have been assessed and can be broadly divided into patient, ventilator and oxygenation parameters.

A. Patient parameters

1. Awake, alert and cooperative
2. Haemodynamically stable
3. Respiratory rate < 30/min
4. No effect of sedation/neuromuscular blockade
5. Minimal secretions
6. Good nutritional status

B. Ventilator parameters

1. Spontaneous tidal volume (TV) > 5 - 8 ml/kg
2. Vital capacity (VC) > 10 - 15 ml/kg,
3. Positive End Expiratory Pressure (PEEP) requirement < 5 cm of H₂O
4. Static compliance > 30 ml/cm of H₂O
5. Minute ventilation < 10 L
6. Ratio of dead space volume to tidal volume (VD/VT) < 60 %
7. Maximal Inspiratory Pressure (MIP/Pi_{max})
8. Negative inspiratory force (NIF)

C. Oxygenation criteria

1. PaCO₂ < 50 mm of Hg with normal pH
2. PaO₂ > 60 @ FiO₂ 0.4 or less
3. SaO₂ > 90 % @ FiO₂ 0.4 or less
4. PaO₂/FiO₂ > 200
5. P(A-a)O₂ < 35 mm of Hg @ FiO₂ of 1.0

FiO₂ = inspiratory oxygen fraction, PaO₂ = partial pressure of oxygen in arterial blood, PAO₂ = partial pressure of oxygen in alveoli, PaCO₂ = partial pressure of carbon dioxide in arterial blood, SaO₂ = arterial oxygen saturation.

Unfortunately none of the variables demonstrate more than a modest accuracy in predicting weaning outcome. Hence, several combined indices were devised in early 1990s to predict weaning failure or success such as

1. Rapid shallow breathing index
2. Simplified weaning index
3. Compliance rate pressure oxygenation index

Rapid shallow breathing index (RSBI)

This is expressed as

$$RSBI = f/VT$$

where f is the respiratory frequency and VT the tidal volume

Several studies have demonstrated that RSBI is superior to conventional parameters in predicting the outcome of weaning. The direction and magnitude of the change from pretest to post-test probability are determined by the likelihood ratio. But in a recent randomized, blinded controlled trial, 304 patients admitted to ICUs were enrolled and RSBI was taken as a major weaning predictor. 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. In another recent study evaluating clinical predictors of weaning failure or success which included 900 patients, extubation failure occurred in 121 (13.4%). Among routinely measured clinical variables, RSBI, positive fluid balance 24 hours prior to extubation and pneumonia at the initiation of ventilation were the best predictors of extubation failure. Interestingly, the threshold value for RSBI was lower (57) as compared to previously used value of 100.

Accuracy of RSBI is significantly affected by the pretest probability of a weaning success. When the pretest probability of weanability is high (> 70%) establishing the RSBI value may be useless in the decision-making process, because a value lower than 100 would only confirm that it is very likely that the patient will wean and a value higher than 100 would not necessarily dismiss success because post-test probabilities between 40 and 60% are possible. Conversely, when the pretest probability of weanability is low (<40%) establishing the RSBI value may be very useful; this is because a value higher than 100 might dismiss an attempt at weaning since the probability of success will be lower than 20%, and a value lower than 100 could encourage an attempt at weaning, taking into account that probabilities of success between 50 and 65% are possible.

Simplified weaning index (SWI) and Compliance rate pressure oxygenation index (CROP)

These are expressed as

$$SWI = fmv(PIP - PEEP)/MIP \times PaCO_2mv/40$$

$$CROP \text{ index} = [CDYN \times MIP \times PaO_2/PAO_2]/f$$

fmv = ventilator frequency, PIP = peak inspiratory pressure, PEEP = positive end expiratory pressure, MIP = maximal inspiratory pressure, PaCO₂mv = partial pressure of carbon dioxide in arterial blood while on MV

CDYN = dynamic compliance, PaO₂ = partial pressure of oxygen in arterial blood, PAO₂ = partial pressure of oxygen in alveoli, f = respiratory frequency

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

But in general practice the decision to use these criteria must be individualized.

Various questions which arise while attempting to wean any patient from mechanical ventilation are:

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

Gradual versus sudden weaning

Data is available is scarce. Most trials have used sudden weaning using spontaneous breathing trial with T-piece, pressure support ventilation (PSV) or continuous positive airway pressure (CPAP). However if a patient fails recurrent weaning attempts, a gradual weaning strategy is advocated.

AVAILABLE MODES OF WEANING

Conventional Modes

1. Spontaneous breathing trials (SBT)
2. Pressure support ventilation (PSV)
3. Synchronized intermittent mandatory ventilation (SIMV)
4. SIMV + PSV

Newer modes

1. Automatic tube compensation (ATC)
2. Adaptive support ventilation (ASV)
3. Auto-mode ventilation
4. Airway pressure release ventilation (APRV)
5. Volume assured pressure support (VAPS)
6. Proportional assist ventilation (PAV)
7. Non invasive positive pressure ventilation (NIPPV)

Conventional Modes

Spontaneous Breathing Trials

Two large randomized trials compared SBT with other modalities for weaning. Esteban et al compared 2 hour trials of unassisted breathing using pressure support (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 hour trial than in the T-piece. Reintubation rates were similar. In another study by same authors, a 30 minute to a 120 minute T-piece trial was compared. There was no difference in the rate of re-intubation between patient groups but patients who were randomized to the shorter T-piece trial benefited from statistically significant reductions in ICU and hospital lengths of stay (2 days and 5 days shorter, respectively).

Other trials done in this area suffer from limitations such as small sample size and bias. However, from analysis of pooled data across two studies, the number of events was so low that the 95% confidence intervals (CIs) were extremely wide [relative risk for nonextubation in CPAP vs T-piece breathing being 1.66 (95% CI, 0.60 to 4.64) while relative risk for reintubation being 1.61 (95% CI, 0.39 to 6.59)].

Pressure Support Ventilation and Synchronized Intermittent Mandatory Ventilation

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. Among them two were large RCTs that compared multiple daily T-piece breathing, PSV and SIMV. Study design was almost similar in both the studies. In comparison of T-piece breathing to PSV, 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 PSV. In a recent randomized prospective study including 260 patients who received mechanical ventilation for more than 48 hours, the total length of additional MV and total length of stay in ICU were significantly shorter in patients undergoing PSV weaning. For the patients with weaning difficulties and APACHE II score >20 on admission, PSV was the superior modality in terms of duration of mechanical ventilation, extubation and reintubation rates. 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 PSV to SIMV on the duration of weaning, both studies found trends in favor of PSV, although the effect in the study by Brochard et al was much larger. In another study including only 19 patients were randomized to SIMV with PSV vs SIMV without PSV. The duration of the weaning process was approximately 1 day shorter in the group that received PSV; with the lower boundary of the 95% CI being approximately 7 hours. Reintubation was required in two patients in the SIMV group, and none in the group that received PSV.

Summarizing, there is a huge discrepancy in results of various available 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. 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. Results of two studies of weaning in 48 hours 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.

However in a systemic review of various trials comparing the popular weaning mode none of modes were identified to superior to other. It appeared that SIMV may lead to a longer duration of the weaning process than either T-piece or PSV.

Finally, the manner in which the mode of weaning is applied may have a greater effect on the likelihood of weaning than the mode itself. The most effective mode of ventilation for weaning still needs to be determined and more work is required in this area.

Newer modes

Automode

This mode is available on Siemens Servo ventilators. It combines volume support (VS) and pressure regulated volume control (PRVC) into one mode. If the patient is paralyzed or apneic, pressure limited time cycled breaths, with variable pressure to achieve desired tidal volume are delivered and if patient breathes spontaneously for 2 breaths it automatically switches to VS at equivalent airway pressure. Little information is available on this mode regarding its clinical utility. In a small recent study time to extubation was 2 hours shorter in patients assigned to automode ventilation (n=10) compared to patients assigned to conventional ventilation (n=10).

Automatic Tube Compensation (ATC)

This mode uses continuous calculation of P_{trach} (tracheal pressure) using known resistive component of endotracheal tube. Measurement of flow and compensation for tube resistance by closed loop control of calculated P_{trach} is done. This results in decrease in work of breathing and also intrinsic PEEP.

Among all 90 patients (30 per group) in one study, no significant difference 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 MV. 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 was 17.7% (95% confidence interval, 0.67-35.5).

For other newer weaning modes no RCTs are available.

Non invasive positive pressure ventilation (NIPPV) for Weaning

Recently attention has focused towards the use of NIPPV in weaning and post extubation respiratory failure. In this method any patient tolerating SBT is extubated and put on NIPPV. All the studies have used mainly patients with chronic respiratory failure especially chronic obstructive pulmonary disease (COPD) and hence should only be used for this subgroup of patients.

In a meta-analysis of studies for use of NIPPV in weaning it was demonstrated that there was decrease duration of ventilation, ICU stay. Decreased incidence of pneumonia and also mortality with the use of NIPPV for weaning was observed.

PROTOCOL VERSUS COMPUTER GUIDED WEANING

In protocol guided weaning the bedside nurse assesses the patient's readiness to wean on a daily basis before the morning 'round' using the first eight objective criteria listed on the daily wean screen (see below).

Daily wean screen

1. Respiratory rate < 30 /min
2. PaO_2/FiO_2 ratio > 200
3. Systolic blood pressure > 90 and < 180 mmHg
4. Temperature < 38.4 C
5. Arterial blood pH > 7.3
6. Haemoglobin > 7.0 g/dL
7. PEEP < 5 cmH₂O
8. Spontaneous tidal volume > 5 ml/kg
9. Underlying indication for MV resolved or significantly improved

The clinical condition of the patient meeting the criteria is discussed on the morning round with the ICU consultant to determine whether the patient's underlying indication for MV has resolved or significantly improved (ninth criterion); if so, weaning is initiated. The choice of protocol depends upon the ventilatory mode the patient was currently receiving at the time of the decision to wean. For example, if the patient was receiving PSV, then the bedside nurse follows the guidelines for stepwise reductions in pressure support. The patient progresses along the weaning protocol unless they meets any of the predetermined respiratory fatigue criteria.

Fatigue criteria

1. Respiratory rate > 35 /min (sustained)
2. Heart rate > 140 /min (sustained)
3. SaO₂ $< 90\%$
4. Systolic blood pressure < 90 or > 180 mmHg
5. Arterial blood pH < 7.28
6. Uncoordinated chest movements
7. Presence of agitation, anxiety, diaphoresis, pain limiting weaning or ischaemic changes on electrocardiogram

Re-initiation of weaning occurs the following morning if the patient once again meets the readiness to wean criteria.

Protocol guided weaning has been compared to physician directed weaning in various trials. But data is sparse and conflicting. Proposed benefit of protocolized weaning are decrease in ventilation time and decreased cost. Also decreased need of staff recruitment has been seen in this subgroup. Few studies have also demonstrated negative results in terms of longer weaning times. 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.

The computer driven system (CDS) is a knowledge-based system embedded in a ventilator. It achieves three main goals:

1. The CDS continuously adjusts the PS level based on respiratory rate (RR), VT and end-tidal partial pressure of CO₂ (PETCO₂) acquired from the ventilator in real time and averaged over 2 min. Adjustment is such that the patient is kept within a "comfort zone" defined as RR in the 15–30 range (up to 34 in patients with neurological disorders), VT greater than 300 ml (>250 ml if body weight <55 kg), and PETCO₂ < 55 mmHg (<65 mmHg in patients with COPD).
2. The CDS manages a strategy of gradually decreasing ventilatory assistance by reducing the PS level after at least 30 min of stable ventilation within the comfort zone; the reduction is 2 or 4 cm H₂O depending on whether the initial level is below or above 20 cm H₂O, respectively.
3. The CDS evaluates weaning readiness: when the PS level reaches the preset minimal value (with a heated humidifier or a filter, respectively of 5 or 9 cm H₂O in tracheotomized patients and 7 or 12 cm H₂O in intubated patients), the CDS starts an observational period, which serves as an automatic "spontaneous breathing" test. After uninterrupted ventilation at the minimal PS level for 1 or 2 hours (depending on whether the initial PS level was above or below 15 cm H₂O), the CDS displays a message that the patient is ready for 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 CDS ventilation was 3 ± 3 days (maximum, 12 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.

In another recent study, 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 days (p = 0.01) and total duration of MV from 12 to 7.5 days (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 days (p = 0.02) and caused no adverse events.

OTHER FACTORS INFLUENCING WEANING

Miscellaneous other interventions have also been evaluated to play a role weaning success or failure:

Fluid Balance

Preliminary data in this regard shows that fluid balance is a potentially modifiable factor and is associated with weaning outcomes. A randomized study is required to determine whether diuresis to treat positive fluid balance expedites liberation from MV. In a small recent study it was observed that negative fluid balance was an independent predictor of weaning success.

Composition of enteral nutrition

The two RCTs of high-fat/low-carbohydrate enteral nutrition showed that this kind of composition was associated with better outcomes. High-fat feeds appear to have favorable physiologic effects on CO₂ production and may be useful in patients with impaired ventilatory reserves. However, these studies were underpowered for clinically important outcomes, and their results require confirmation or refutation. Future RCTs in this area should enroll large numbers of difficult-to-wean COPD patients and should measure both physiologic and clinically important outcomes, such as the duration of MV. The influence of enteral versus parenteral nutrition on weaning success and the duration of ventilation in patients receiving long-term ventilation would be useful.

Oximetry and capnography

In the RCT of oximetry and capnography to monitor patients during weaning, approximately half as many blood gas analyses were performed compared to the control arm. However, the control patients were already getting approximately one blood gas analysis every 2 hours. Such a dramatic benefit is unlikely to be seen in practice today, since this baseline blood gas frequency is highly atypical except for unstable or very difficult-to-wean patients.

Other interventions like relaxation biofeedback and acupuncture have also been studied but are still in their infancy and need further studies.

Role of tracheostomy

Tracheostomy can expedite weaning by various beneficial effects like:

1. Improved patient comfort
2. More effective airway suctioning
3. Decreased airway resistance

4. Enhanced patient mobility
5. Increased opportunities for articulated speech
6. Ability to eat orally, a more secure airway
7. Accelerated weaning from mechanical ventilation
8. Ability to transfer ventilator-dependent patients from ICU

In few studies done for evaluating the role of tracheotomy in weaning it has been seen that early tracheotomy performed within the first 7 days of mechanical ventilation decreases the duration of MV. Tracheotomy reduces the work of breathing of ventilator dependent patients.

Early and late tracheostomy have 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 tracheotomized in some studies but not in others.

Conclusions

Selection of a particular mode for weaning should be determined by its availability and physician experience. Once daily T-piece weaning or PSV is superior to SIMV. Early extubation with back up ventilation of NIPPV is useful especially in patients with COPD. Role of newer modes in weaning is still unclear and requires more studies. Protocol and computer directed protocols may be helpful in open and less staffed ICUs.

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National Conference on Pulmonary Diseases

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