Role of Noninvasive Mechanical Ventilation in Difficult Weaning

56

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Contents

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56.1 Introduction

Mechanical ventilation is an essential part of the management of critically ill patients. It involves provision of positive pressure, either using invasive (endotracheal tube, tracheostomy) or noninvasive (oronasal or face mask) methods. The use of invasive mechanical ventilation is associated with several complications, both infectious (ventilator-associated pneumonia) and noninfectious (volutrauma, barotrauma, ventilator-induced diaphragmatic dysfunction, and others). Hence, in several situations, especially acute exacerbations of chronic obstructive pulmonary disease (COPD) and cardiogenic pulmonary edema, a trial of noninvasive ventilation (NIV) is preferred prior to intubation [1–6]. However, in some clinical circumstances, endotracheal intubation is inevitable [7–10]. Once the underlying respiratory illness starts recovering, the patient is ready to be weaned off the mechanical ventilatory support. Weaning is defined as a process that involves liberation of a person from mechanical ventilation and from the endotracheal/tracheostomy tube [11].

The management of a patient with respiratory failure comprises of a continuum of six steps [11]: (1) treatment of acute respiratory failure; (2) diagnosis of the probability of weaning; (3) assessment for weaning; (4) determination of the ability of a patient to breathe spontaneously through a spontaneous breathing trial (SBT); (5) removal of the endotracheal tube (extubation); and (6) reintubation, if the patient is unable to breathe spontaneously. Failure in identification of stage 2 and assessment of readiness to wean (stage 3) is considered the most important factor responsible for delay in weaning. Delay in weaning or prolonged mechanical ventilation has several adverse outcomes, including increased risk of ventilator-associated complications, and adds to the cost of management [12–14]. In this chapter, we review the role of NIV in weaning patients from invasive ventilation in critical care. We specifically look at the role of NIV in facilitating extubation in patients who fail SBT, without discussing the role of NIV in established post-extubation respiratory failure or the role of NIV in preventing reintubation in those with planned extubation (as a preemptive strategy for preventing reintubation) [15].

56.2 Definitions

56.2.1 Weaning Failure

Weaning failure is defined as either failure of SBT or need for reintubation or death within 48 h of extubation [11]. Failure of SBT is characterized by a combination of objective (respiratory rate >30 breaths/min, heart rate of >110 beats/min, hypotension, cardiac arrhythmias, hypoxemia, or acidosis) and subjective (agitation, altered mental status, diaphoresis, labored breathing, and others) parameters [7–9, 16–19].

56.2.2 Weaning in Progress

Weaning in progress is a term used to define an intermediate category of weaning process wherein the patient is liberated from invasive mechanical ventilation but needs the support of NIV to facilitate weaning [11]. Patients with difficult weaning have high morbidity and mortality up to 40 %. Patients with prolonged weaning usually require long-term ventilatory support, with only 50 % alive at 5 years [11].

56.2.3 Classification of Weaning

Weaning is classified into three categories [11]: (1) simple weaning is a condition in which the patient proceeds from initiation of weaning to successful extubation on the first attempt without difficulty; (2) difficult weaning is a condition in which the patient fails initial weaning and requires up to three SBTs or as many as 7 days from the first SBT to achieve successful weaning; (3) prolonged weaning is a condition in which the patient fails at least four weaning attempts or requires >7 days of weaning after the first SBT.

56.2.4 Criteria for Weaning

The decision to initiate the weaning process is a clinical art and requires a combination of certain criteria (Table 56.1) that need to be accomplished before applying weaning assessment methods.

56.3 Pathophysiology of Weaning Failure

Patients who face weaning difficulties usually develop rapid shallow breathing on liberation from positive pressure ventilation. This results in dynamic hyperinflation and development of intrinsic positive end-expiratory pressure (iPEEP) [6, 20, 21]. The iPEEP, along with high ventilatory demand, leads to an increase in the respiratory work of breathing and causes respiratory muscle fatigue, thus causing weaning failure. The increase in respiratory work of breathing is further compounded by cardiovascular responses associated with removal of positive pressure ventilation, leading to an increase in the venous return along with escalation in resistance to left ventricular outflow [22]. An inappropriate cardiovascular response, especially in those with compromised left ventricular function, further increases the load on already-burdened respiratory muscles [23].

Table 56.1 Criteria for readiness for weaning (combination of one or more of the following)

Subjective parameters
Resolution of the disease for which the patient needed ventilatory support
Good effective cough/ability to clear secretions
Absent or minimal tracheobronchial secretions
Clear sensorium/ no delirium
Absent or minimal neuromuscular weakness
Objective parameters
Respiratory rate ≤35/min
Heart rate ≤140/min
Resolution of hypotension or minimal need of vasopressors
SpO_2 >89 % on ≤ FiO_2 0.4 (or Pa_{O_2} / Fi_{O_2} ≥150mmHg)
PEEP ≤8 cmH_2O
Pa_{CO_2} ≤ 45mmHg
MIP ≤ −20 to −25 cmH_2O
V_T >5 ml/kg
RSBI <105 breaths/min/l

MIP maximum inspiratory pressure, *PEEP* positive end expiratory pressure, *RSBI* rapid shallow breathing index, *VT* tidal volume

56.4 Assessment Tools for Weaning

A weaning assessment tool should ideally be able to correctly identify all the individuals who can be safely liberated from the ventilator. Patients who meet the weaning criteria should be screened with one of the weaning assessment tools. The various weaning assessment tools include respiratory frequency-to-tidal volume ratio, maximum inspiratory pressure, integrative weaning index, diaphragm ultrasound, and others. The currently available methods for weaning assessment are far from perfect, thus creating a need for an ideal assessment tool.

56.4.1 Respiratory Frequency-to-Tidal Volume Ratio (f/V_T)

Also known as rapid shallow breathing index (RSBI), the f/V_T is measured during spontaneous breathing for 1 min. During spontaneous breathing, the ventilator is set at a pressure support of 0 cm of H_2O or continuous positive airway pressure (CPAP) of 0 cm H_2O. A RSBI of 100 discriminates between successful weaning and failure, with a value of <100 suggesting a successful weaning trial with a sensitivity of 0.97 and a specificity of 0.65 [24].

56.4.2 Diaphragm Ultrasonography

Mechanical ventilation can lead to rapidly progressive diaphragmatic weakness and may hinder weaning from ventilation [25]. Bedside ultrasound is a useful modality to assess the diaphragm function. In a single-center study involving mechanically ventilated patients, diaphragm dysfunction (excursion of <10 mm on M-mode) could be identified in 29 % patients by using bedside ultrasound. Presence of diaphragmatic dysfunction on ultrasound assessment was associated with prolonged weaning time (17 vs 4 days, $p<0.01$) and a longer time spent on mechanical ventilation (24 vs 9 days, $p<0.01$) [26].

56.4.3 Integrative Weaning Index

A prospective study assessed a combination of several factors (respiratory system compliance x arterial oxygen saturation/f/V_T ratio) to predict the weaning from mechanical ventilation. The Integrative Weaning Index (IWI) performed better than several other parameters, including RSBI, tidal volume (V_t), tracheal airway occlusion pressure in the first 0.1 s (P 0.1), the product of P 0.1 and f/V_t ($P\ 0.1 \times f/V_t$), respiratory rate (f), static compliance of the respiratory system (Cst), and ratio of arterial oxygen tension to fraction of inspired oxygen (PaO_2/FiO_2) with an area under the receiver-operating characteristic (ROC) curve of 0.96 [27].

56.5 Weaning Trials

Once the patient is assessed for weaning and is considered suitable for weaning, a weaning trial is instituted before extubation. An ideal weaning trial should be able to identify all the individuals who will successfully tolerate extubation. The weaning techniques that are used include SBT, automated tube compensation, pressure support ventilation (PSV), and synchronized intermittent mechanical ventilation (SIMV).

56.5.1 Spontaneous Breathing Trial

SBT is the oldest and most commonly employed method used for weaning [16]. It involves removing the patient from the ventilator and providing supplemental oxygen by using a T-piece or T-tube device or a pressure support of 5–8 cm of H_2O in adults [19, 28–30]. A pooled analysis of nine randomized trials comparing PSV SBT versus T-piece trial SBT did not find any difference between the methods or the pressure used in weaning success, intensive care unit (ICU) mortality, reintubation rate, length of stay in ICU or long-term weaning unit, and pneumonia [30]. However, PSV was more effective in predicting successful

SBT in patients with simple weaning compared with T-piece trial [19, 30]. A few studies have also used CPAP of 5 cm H_2O for SBT [30]. It is reasoned that provision of CPAP maintains functional residual capacity at a level similar to that following extubation. Further, CPAP also helps maintain the patency of small airways, especially in patients with COPD [31]. However, in patients with poor left ventricular function, provision of CPAP may falsely predict successful extubation [23].

56.5.2 Pressure Support Ventilation

PSV is another commonly used method for weaning. With PSV, all the breaths are patient triggered, flow cycled, and provide ventilatory support that is gradually reduced over time until patient is successfully liberated from mechanical ventilation. Both inspiratory positive airway pressure (IPAP) or pressure support and expiratory positive airway pressure (EPAP) or CPAP are reduced gradually by 1–2 cm of H_2O until an acceptable IPAP of 5–7 cm of H_2O and EPAP of 0–5 cm of H_2O is reached [19].

56.5.3 Synchronized Intermittent Mandatory Ventilation

With SIMV, ventilation is assisted intermittently either as mandatory or as spontaneous breaths. During the spontaneous mode there is no support to the respiratory muscle, which have an additional burden to overcome dead space due to ventilatory circuit [5, 32]. This increased burden leads to fatigue of respiratory muscles and hence weaning failure and increased need for invasive mechanical ventilation. Therefore, the use of SIMV as a mode for weaning is discouraged. SIMV can also be combined with PSV, where the spontaneous breaths are assisted by pressure support. However, even this mode is inferior as the respiratory center and respiratory muscles have to alter their output in anticipation of the next breath, which may either be mandatory or spontaneous. Moreover, it does not does not allow partitioning of the work of breathing performed by either the ventilator or the patient [5, 32–35].

56.6 Role of NIV in Weaning

Noninvasive ventilation has been used in three different scenarios for weaning: (i) advancing extubation in patients with difficult or prolonged weaning (weaning strategy); (ii) avoidance of reintubation after extubation in patients with post-extubation respiratory failure (management strategy); and (iii) to prevent development of post extubation respiratory failure (prophylactic strategy). Herein, we discuss only the weaning strategy.

56.6.1 Rationale of NIV in Weaning Failure

By reducing the work of breathing and preventing the development of the rapid shallow breathing pattern, NIV may be useful where weaning has failed. Further, EPAP akin to positive end-expiratory pressure acts as an external splint and helps in avoiding dynamic hyperinflation seen in patients with COPD. NIV by its favorable cardiovascular effects may also facilitate weaning [3, 4, 6, 15, 36, 37].

56.7 Role of NIV in Difficult/Prolonged Weaning (Weaning Strategy)

NIV has been tried in the management of acute respiratory failure as a strategy to shorten the weaning process and facilitate liberation from invasive mechanical ventilation, especially in patients with COPD [38–40]. The trial design in most studies involved patients who failed SBT; they were subsequently randomized to continued invasive ventilation or extubated and initiated on NIV. The results of nine randomized controlled trials (RCTs) evaluating the role of NIV in augmenting extubation are summarized in Tables 56.2 and 56.3. Of the nine studies identified, three studies included patients with acute exacerbation of COPD (AECOPD) [38–40], while three studies encompassed patients with acute respiratory failure due to heterogeneous etiology (COPD, heart failure, pneumonia, thoracic trauma, and chest wall deformity) [41–43]. One study comprised patients with acute hypoxemic respiratory failure [44], and two studies involved patients with acute-on-chronic respiratory failure (COPD, persistent asthma, bronchiectasis, obesity hypoventilation syndrome, restrictive lung diseases, and others) [45, 46]. The most common weaning assessment tool applied in all the studies was SBT with duration ranging between 5 min and 2 h. Weaning success, as defined by the lack of need of reintubation within 48–72 h of extubation or hospital survival, was reported in eight studies. Other parameters reported included duration of invasive mechanical ventilation, length of ICU/hospital stay, hospital mortality, and complications associated with invasive mechanical ventilation and weaning.

56.7.1 NIV in Weaning Patients with AECOPD

Three randomized trials involving 120 patients of acute exacerbation of COPD have assessed the role of NIV in weaning patients with AECOPD [38–40]. Weaning success (avoidance of re-intubation) was reported in two studies. The use of NIV was associated with successful weaning in 86 % (39/45) of the patients, whereas the use of conventional methods led to successful weaning in 71 % (32/45). In comparison with invasive mechanical ventilation, the use of NIV was associated with a comparable improvement in arterial blood gas and clinical parameters such as respiratory rate and sensorium, and a lesser incidence of

Table 56.2 Summary of studies describing use of noninvasive pressure ventilation (NIV) in difficult weaning

Author/year of study	Type of study	No. of patients	Comparator strategy (*n*)	Cause of respiratory failure	Weaning trial given	Weaning success (*p* value)
Nava et al. (1998) [38]	RCT	50	NIV vs PSV (25 vs 25)	AECOPD	T-piece trial	22/25 vs 17/25 (0.002)
Girault et al. (1999) [46]	RCT	33	NIV vs PSV (17 vs 16)	AECOPD, restrictive lung disease, mixed lung disease	2 h T-piece trial	13/17 vs 12/16 (>0.05)
Ferrer et al. (2003) [41]	RCT	43	NIV vs conventional weaning strategy (21 vs 22)	AECOPD, heart failure, pneumonia, thoracic trauma, post-operative	T-piece trial	18/21 vs 16/22 (>0.05)
Trevisan at al. (2008) [43]	RCT	65	NIV vs IMV (28 vs 37)	AECOPD, heart failure, pneumonia, thoracic trauma, post-operative	30 min T-piece trial	15/28 vs 15/37 (NA)
Prasad et al. (2009) [40]	RCT	30	NIV vs PSV (15 vs 15)	AECOPD	2 h T-piece trial	NA
Girault et al. (2011) [45]	RCT	208	NIV vs PSV vs oxygen therapy (69 vs 69 vs 70)	Chronic hypercapnic respiratory failure due to COPD, persistent asthma, bronchiectasis, obesity-hypoventilation syndrome, chest wall deformity, sequelae of pulmonary tuberculosis	5 mins-2 h T-piece trial	46 vs 32 vs 20 (<0.001)
Vaschetto et al. (2012) [44]	RCT	20	NIV vs PSV (10 vs 10)	Acute hypoxemic respiratory failure	30 min SBT	9/10 vs 5/10
Tawfeek et al. (2012) [42]	RCT	42	NIV vs SIMV (21 vs 21)	AECOPD, heart failure, pneumonia, thoracic trauma, post-operative, neuromuscular disease	2 h SBT	18/21 vs 11/21 (<0.05)
El-Shimy et al. (2013) [39]	RCT	40	NIV vs SIMV (20 vs 20)	AECOPD	0.5–2 h SBT	17/20 vs 15/20 (0.049)

AECOPD acute exacerbation of COPD, *COPD* chronic obstructive pulmonary disease, *IMV* invasive mechanical ventilation, *PSV* pressure support ventilation, *RCT* randomized control trial, *SBT* spontaneous breathing trial, *SIMV* synchronized intermittent mandatory ventilation

Table 56.3 Outcome parameters in studies describing noninvasive ventilation as a weaning strategy

Author/year	Total duration of IMV, in days	Total duration of ventilatory support (both NIV and IMV), in days	Length of ICU stay, in days	Length of hospital stay, in days	In hospital deaths (*n*)	Complication related to IMV and weaning (*n*)
Nava et al. (1998) [38]	10.2±6.8 vs 16.6±11.8	NA	15.1±5.4 vs 24±13.7	NA	2 vs 7	NA
Girault et al. (1999) [46]	4.56±1.85 vs 7.69±3.79	11.54±5.24 vs 3.46±1.42	12.35±6.82 vs 14.06±7.54	27.12±14.33 vs 27.69±13.09	0 vs 2	6 vs 9
Ferrer et al. (2003) [41]	9.5±8.3 vs 20.1±13.1	11.4±8 vs 20.1±13.1	14.1±9.2 vs 25±12.5	27.8±14.6 vs 40.8±21.4	2 vs 9	5 vs 16
Trevisan et al. (2008) [43]	7.5±7.8 vs 10±9.1	14.9±9.9 vs 17.3±10.5	18.9±11.3 vs 20.8±10.9	34.5±20.6 vs 42.4±24.5	9 vs 10	8 vs 28
Prasad et al. (2009) [40]	6.20±5.20 vs 7.47±6.38	NA	8.47±4.79 vs 10.80±5.28	NA	5 vs 9	6 vs 5
Girault et al. (2011) [45]			7.5 [4.5–15.5] vs 7.5 [4.5–14.5] vs 7.5 [4.5–17.5][a]	17.5 [9.5–28] vs 7.5 [4.5–14.5] vs 7.5 [4.5–17.5][a]	16 vs 9 vs 9	33 vs 35 vs 43
Vaschetto et al. (2012) [44]	8 vs 15	NA	15±11 vs 21±13	NA	2 vs 3	3 vs 5
Tawfeek et al. (2012) [42]	12.8±8.3 vs 22.3±13.3	NA	NA	NA	2 vs 6	4 vs 19
El-Shimy et al. (2013) [39]	35±1.63 vs 47±2.25	NA	9.50±3.2 vs 11.4±2.70	NA	5 vs 9	0 vs 16

All values are expressed as mean±SD unless otherwise stated
IMV invasive mechanical ventilation, *NA* not available

[a]Median with interquartile range

nosocomial pneumonia. The use of NIV was not without complications, which included dryness of mouth, abrasion of nasal skin, claustrophobia, gastric distension, poor quality of sleep, and others.

The first RCT included 50 patients with severe COPD [38], with 35 of these patients receiving long-term oxygen therapy. Most patients (approximately 50 %) had comorbid illnesses, including rhythm disturbances, hypertension, diabetes mellitus, heart failure, and others. The application of NIV for weaning significantly reduced the need for invasive ventilation and ICU stay; it was associated with a higher 60-day survival. The other two trials did not mention the severity of underlying COPD and comorbid conditions [39, 40]. In the two trials reporting the weaning time, the NIV group had shorter weaning times in comparison with the control arm (invasive mechanical ventilation) [39, 40]. Further, the mean IPAP and EPAP (15.07 ± 1.27 and 6.21 ± 0.43 cm of H_2O, respectively) in the NIV arm and the mean pressures in the invasive arm (18.21 ± 1.1 cm of H_2O above PEEP of 5 cm of H_2O) were similar in the two groups [40].

Thus, in carefully selected patients with AECOPD who fail initial weaning trials, the use of NIV may be associated with a reduction in weaning time, less need for invasive mechanical ventilation, lower incidence of nosocomial pneumonia, better survival rates, and superior weaning rates.

56.7.2 NIV in Weaning Patients of Acute Hypoxemic Respiratory Failure

Only one single-center feasibility study has described the use of NIV as a weaning strategy in patients with acute hypoxemic respiratory failure [44]. Ten patients each were randomized to undergo either a NIV-based strategy or a conventional (invasive PSV) strategy for weaning from invasive mechanical ventilation. The etiology of ARDS included both direct (thoracic trauma, aspiration pneumonia, pneumonia) and indirect (sepsis, pancreatitis, blood transfusion related) causes, with baseline Acute Physiology and Chronic Health Evaluation (APACHE) II scores ranging from 8 to 13. Extubation failure was defined as an inability to sustain spontaneous unassisted breathing for 48 consecutive hours without the need for invasive or noninvasive ventilation. The use of NIV resulted in weaning success in 90 % of the patients compared with 50 % in the conventional arm. There were three ICU deaths in the conventional arm and only one death in the NIV arm. Three patients in the invasive PSV arm required tracheostomy, whereas none needed tracheostomy in the NIV arm. The most common cause of death was multiorgan failure. One additional patient in the NIV arm succumbed to underlying comorbid illness (chronic kidney disease and diabetes mellitus) after discharge from the ICU. Although NIV resulted in a significantly shorter duration of invasive ventilation, overall 28-day ventilation-free days (invasive and NIV) and weaning time were similar in the two groups.

There is sparse evidence on the role of NIV in facilitating extubation in patients recovering from acute hypoxemic respiratory failure. Thus, NIV should not be used

in weaning this group of patients. More evidence is required regarding the use of NIV in weaning patients with acute hypoxemic respiratory failure.

56.7.3 NIV in Weaning Patients with Acute-on-Chronic Respiratory Illness

Two trials have addressed the role of NIV in acute-on-chronic respiratory diseases [45, 46]. Both trials included patients ($n = 241$) with chronic respiratory disorders such as COPD, persistent asthma, bronchiectasis, restrictive lung disorders, and others. In the first trial, 33 patients were randomized to either NIV ($n = 17$) or the conventional mode of weaning ($n = 16$) [46]. Weaning failure was defined as inability to sustain unassisted ventilation for at least 5 days or death or reintubation. Most of the included patients had severe underlying disease as defined by previous history of intubation ($n = 12$) or need for long-term oxygen therapy (LTOT) ($n = 10$). Although the NIV group had fewer days on invasive mechanical ventilation, there was no difference in weaning success, mortality, or complications. A subsequent larger multi-center study randomized patients ($n = 208$) into three groups (NIV group, invasive PSV, and oxygen therapy group) [45]. Patients in the non-NIV group were allowed NIV trial prior to reintubation, after extubation failure. Weaning failure was defined as an inability to sustain unassisted ventilation for at least 7 days or death or reintubation. The duration of 7 days was included to account for late NIV failure. In this study also, apart from a decline in the duration of invasive mechanical ventilation, no difference was seen in the weaning success rate, hospital mortality, or complications. The lack of difference in this study could be explained by the use of NIV prior to reintubation in both the non-NIV arms.

Thus, current evidence supports judicious use of NIV as a weaning strategy in patients with chronic respiratory diseases, as NIV may improve weaning results in these patients by shortening the duration of intubation and reducing the risk of post-extubation acute respiratory failure.

56.7.4 NIV in Weaning Patients with Acute Respiratory Failure of Heterogeneous Causes

Three trials have addressed the role of NIV in weaning from invasive mechanical ventilation in acute respiratory failure due various causes such as acute exacerbation of COPD, asthma, heart failure, postoperative respiratory failure, thoracic trauma, post-tuberculosis sequelae, pneumonia, and others [41–43]. The initial trial randomized 43 consecutive patients with acute respiratory failure in two arms using either NIV or the conventional approach (invasive PSV) as a weaning strategy [41]. Patients who failed SBT for 3 consecutive days and were considered difficult to wean were enrolled in the study. Successful weaning was defined as ability to sustain spontaneous breathing at least for 3 consecutive days and

extubation failure was defined as the need for reintubation within 72 h of extubation. The use of NIV resulted in significant reduction in duration of total and invasive mechanical ventilation and ICU and hospital stay, better hospital survival, fewer complications, and need for tracheostomy. There was no difference in the reintubation rate in the two study arms, although the patients in the conventional arm were allowed a trial of NIV before attempting reintubation. Use of the conventional weaning approach (odds ratio (OR), 6.6; 95 % confidence interval (CI), 1.1–38.8) and age >70 years (OR, 5.1; 95 % CI, 1.7–15) had higher odds of death in the study population on multivariate analysis [41]. In another trial of 65 patients with a similar study population, the use of NIV resulted in less risk of complications and a trend toward shorter ICU and hospital stay. The patients in this study were sicker at baseline compared with the previous study and had multiple comorbidities [43]. A study of 42 patients compared NIV using proportional assist ventilation (PAV) with conventional weaning using SIMV with pressure support (SIMV-PS); PAV-NIV resulted in significantly higher weaning success with shorter duration of mechanical ventilation and fewer complications (ventilator-associated pneumonia, pneumothorax, sepsis, and others) [42]. There was no difference in the 60-day survival. However, the positive results in this study could also be the result of the use of the SIMV mode for weaning in the comparator arm that has been associated with poor outcomes [18].

Thus, the current evidence suggests a possible role of NIV in reducing the duration of invasive mechanical ventilation in weaning patients with heterogeneous causes of respiratory failure. However, variable results in the three studies do not provide conclusive evidence in support of NIV in reducing mortality or ICU and hospital stay and improving weaning success.

Conclusion

The use of NIV in difficult weaning should be restricted in patients with COPD and other hypercapnic respiratory failure states such as bronchiectasis and chronic asthma. In our ICU, we use NIV as a tool for weaning patients with the aforementioned conditions who fail two attempts at weaning using the SBT strategy (Table 56.4). Importantly, a strict vigil needs to be maintained to identify NIV failure and intubate the patients at the earliest sign of failure.

Table 56.4 Practical approach to the use of NIV in difficult weaning

Underlying conditions	Chronic obstructive pulmonary disease
	Long standing asthma
	Bronchiectasis
Weaning readiness	Significant improvement in the underlying condition
	Respiratory rate <32 breaths/min
	Fi_{O_2} requirement less than 0.4
	PEEP ≤5 cm H_2O
	Good cough reflex
	Normal in mental status
	Minimal airway secretions
	Hemodynamically stable
Spontaneous breathing trial failure	At least on two occasions defined by one or more of the following:
	Increase in respiratory rate ≥40 breaths/min (or >25 % of baseline)
	Sp_{O_2} <85% despite Fi_{O_2} of 0.5
	Pa_{CO_2} >55mmHg (or >20 % of baseline) and pH <7.3
	Heart rate >140 beats/min or <50 beats/min (or increase or decrease by >25 % of baseline)
	Alteration in mental status or agitation associated with diaphoresis
	Hypotension (systolic BP <90 mmHg) or hypertension (systolic BP >180 mmHg)
	Cardiac arrhythmia
NIV application	Full face mask
	Start with IPAP of 8 cm H_20 and EPAP of 4 cm H_20
	Titrate to clinical endpoints of respiratory rate <30 breaths/min; $Sp_{O_2} \geq 90\%$ with $Fi_{O_2} < 0.4$; $Pa_{CO_2} < 50$mmHg with pH between 7.3 and 7.4
NIV failure (defined at 30 min and 1 h)	Increase in respiratory rate ≥40 breaths/min (or >25 % of baseline)
	Sp_{O_2} <85% despite Fi_{O_2} of 0.5
	Pa_{CO_2} >55mmHg (or >20 % of baseline) and pH <7.3
	Heart rate >140 beats/min or <50 beats/min (or increase or decrease by >25 % of baseline)
	Alteration in mental status or agitation associated with diaphoresis
	Hypotension (systolic BP <90 mmHg) or hypertension (systolic BP >180 mmHg)
	Cardiac arrhythmia
	Pooling of secretions
	Gasping respiration

BP blood pressure, *PEEP* positive end expiratory pressure

References

1. Agarwal R. Noninvasive ventilation in acute lung injury/acute respiratory distress syndrome. In: Esquinas AM, editor. Noninvasive mechanical ventilation: theory, equipment, and clinical applications. Berlin: Springer; 2010. p. 241–8.
2. Agarwal R, Aggarwal AN, Gupta D. Non-invasive ventilation in acute asthma. Int J Tuberc Lung Dis. 2006;10(10):1182–3.
3. Agarwal R, Aggarwal AN, Gupta D. Role of noninvasive ventilation in acute lung injury/acute respiratory distress syndrome: a proportion meta-analysis. Respir Care. 2010; 55(12):1653–60.
4. Agarwal R, Aggarwal AN, Gupta D, Jindal SK. Non-invasive ventilation in acute cardiogenic pulmonary oedema. Postgrad Med J. 2005;81(960):637–43.
5. Sassoon CS, Del Rosario N, Fei R, Rheeman CH, Gruer SE, Mahutte CK. Influence of pressure- and flow-triggered synchronous intermittent mandatory ventilation on inspiratory muscle work. Crit Care Med. 1994;22(12):1933–41.
6. Agarwal R, Gupta R, Aggarwal AN, Gupta D. Noninvasive positive pressure ventilation in acute respiratory failure due to COPD vs. other causes: effectiveness and predictors of failure in a respiratory ICU in North India. Int J Chron Obstruct Pulmon Dis. 2008;3(4):737–43.
7. Agarwal R, Handa A, Aggarwal AN, Gupta D, Behera D. Outcomes of noninvasive ventilation in acute hypoxemic respiratory failure in a respiratory intensive care unit in north India. Respir Care. 2009;54(12):1679–87.
8. Gupta D, Nath A, Agarwal R, Behera D. A prospective randomized controlled trial on the efficacy of noninvasive ventilation in severe acute asthma. Respir Care. 2010;55(5):536–43.
9. Sharma S, Agarwal R, Aggarwal AN, Gupta D, Jindal SK. A survey of noninvasive ventilation practices in a respiratory ICU of North India. Respir Care. 2012;57(7):1145–53.
10. Agarwal R, Reddy C, Aggarwal AN, Gupta D. Is there a role for noninvasive ventilation in acute respiratory distress syndrome? Respir Med. 2006;100(12):2235–8.
11. Boles JM, Bion J, Connors A, et al. Weaning from mechanical ventilation. Eur Respir J. 2007;29(5):1033–56.
12. Esteban A, Alia I, Ibanez J, Benito S, Tobin MJ. Modes of mechanical ventilation and weaning. A national survey of Spanish hospitals The Spanish Lung Failure Collaborative Group. Chest. 1994;106(4):1188–93.
13. Ely EW, Baker AM, Dunagan DP, et al. Effect on the duration of mechanical ventilation of identifying patients capable of breathing spontaneously. N Engl J Med. 1996; 335(25):1864–9.
14. Wagner DP. Economics of prolonged mechanical ventilation. Am Rev Respir Dis. 1989;140 (2 Pt 2):S14–8.
15. Agarwal R, Aggarwal AN, Gupta D, Jindal SK. Role of noninvasive positive-pressure ventilation in postextubation respiratory failure: a meta-analysis. Respir Care. 2007;52(11):1472–9.
16. Esteban A, Frutos F, Tobin MJ, et al. A comparison of four methods of weaning patients from mechanical ventilation. Spanish Lung Failure Collaborative Group. N Engl J Med. 1995;332(6):345–50.
17. Vallverdu I, Calaf N, Subirana M, Net A, Benito S, Mancebo J. Clinical characteristics, respiratory functional parameters, and outcome of a two-hour T-piece trial in patients weaning from mechanical ventilation. Am J Respir Crit Care Med. 1998;158(6):1855–62.
18. Brochard L, Rauss A, Benito S, et al. Comparison of three methods of gradual withdrawal from ventilatory support during weaning from mechanical ventilation. Am J Respir Crit Care Med. 1994;150(4):896–903.
19. Gnanapandithan K, Agarwal R, Aggarwal AN, Gupta D. Weaning by gradual pressure support (PS) reduction without an initial spontaneous breathing trial (SBT) versus PS-supported SBT: a pilot study. Rev Port Pneumol. 2011;17(6):244–52.
20. Jubran A, Tobin MJ. Passive mechanics of lung and chest wall in patients who failed or succeeded in trials of weaning. Am J Respir Crit Care Med. 1997;155(3):916–21.

21. Jubran A, Tobin MJ. Pathophysiologic basis of acute respiratory distress in patients who fail a trial of weaning from mechanical ventilation. Am J Respir Crit Care Med. 1997;155(3):906–15.
22. Pinsky MR. Cardiovascular issues in respiratory care. Chest. 2005;128(5 Suppl 2):592s–7.
23. Lemaire F, Teboul JL, Cinotti L, et al. Acute left ventricular dysfunction during unsuccessful weaning from mechanical ventilation. Anesthesiology. 1988;69(2):171–9.
24. Yang KL, Tobin MJ. A prospective study of indexes predicting the outcome of trials of weaning from mechanical ventilation. N Engl J Med. 1991;324(21):1445–50.
25. Jaber S, Petrof BJ, Jung B, et al. Rapidly progressive diaphragmatic weakness and injury during mechanical ventilation in humans. Am J Respir Crit Care Med. 2011;183(3):364–71.
26. Kim WY, Suh HJ, Hong SB, Koh Y, Lim CM. Diaphragm dysfunction assessed by ultrasonography: influence on weaning from mechanical ventilation. Crit Care Med. 2011;39(12):2627–30.
27. Nemer SN, Barbas CS, Caldeira JB, et al. A new integrative weaning index of discontinuation from mechanical ventilation. Crit Care. 2009;13(5):R152.
28. Kollef MH, Shapiro SD, Silver P, et al. A randomized, controlled trial of protocol-directed versus physician-directed weaning from mechanical ventilation. Crit Care Med. 1997; 25(4):567–74.
29. Matic I, Majeric-Kogler V. Comparison of pressure support and T-tube weaning from mechanical ventilation: randomized prospective study. Croat Med J. 2004;45(2):162–6.
30. Ladeira MT, Vital FM, Andriolo RB, Andriolo BN, Atallah AN, Peccin MS. Pressure support versus T-tube for weaning from mechanical ventilation in adults. Cochrane Database Syst Rev. 2014;5:Cd006056.
31. Hess D. Ventilator modes used in weaning. Chest. 2001;120(6 Suppl):474s–6.
32. Marini JJ, Smith TC, Lamb VJ. External work output and force generation during synchronized intermittent mechanical ventilation. Effect of machine assistance on breathing effort. Am Rev Respir Dis. 1988;138(5):1169–79.
33. Imsand C, Feihl F, Perret C, Fitting JW. Regulation of inspiratory neuromuscular output during synchronized intermittent mechanical ventilation. Anesthesiology. 1994;80(1):13–22.
34. Leung P, Jubran A, Tobin MJ. Comparison of assisted ventilator modes on triggering, patient effort, and dyspnea. Am J Respir Crit Care Med. 1997;155(6):1940–8.
35. Hess DR. Ventilator modes: where have we come from and where are we going? Chest. 2010;137(6):1256–8.
36. Agarwal R. Noninvasive ventilation in in post-extubation respiratory failure. In: Esquinas AM, editor. Noninvasive mechanical ventilation: theory, equipment, and clinical applications. Berlin: Springer; 2010. p. 305–14.
37. Agarwal R, Gupta D. What is the role of noninvasive ventilation in diastolic heart failure? Intensive Care Med. 2005;31(10):1451; author reply 1452.
38. Nava S, Ambrosino N, Clini E, et al. Noninvasive mechanical ventilation in the weaning of patients with respiratory failure due to chronic obstructive pulmonary disease. A randomized, controlled trial. Ann Intern Med. 1998;128(9):721–8.
39. El-Shimy WS, Barima MA, Abo El-Magd GH, Mansour SA. Non invasive ventilation versus synchronized intermittent mandatory ventilation with pressure support in weaning of COPD patients: comparative study. Egyp J Chest Dis Tuberculosis. 2013;62(1):159–66.
40. Prasad SB, Chaudhry D, Khanna R. Role of noninvasive ventilation in weaning from mechanical ventilation in patients of chronic obstructive pulmonary disease: an Indian experience. Indian J Crit Care Med. 2009;13(4):207–12.
41. Ferrer M, Esquinas A, Arancibia F, et al. Noninvasive ventilation during persistent weaning failure: a randomized controlled trial. Am J Respir Crit Care Med. 2003;168(1):70–6.
42. Tawfeek MM, Ali Elnabtity AM. Noninvasive proportional assist ventilation may be useful in weaning patients who failed spontaneous breathing trial. Egyp J Anaesthes. 2012; 28(1):89–94.
43. Trevisan CE, Vieira SR. Noninvasive mechanical ventilation may be useful in treating patients who fail weaning from invasive mechanical ventilation: a randomized clinical trial. Crit Care. 2008;12(2):R51.

44. Vaschetto R, Turucz E, Dellapiazza F, et al. Noninvasive ventilation after early extubation in patients recovering from hypoxemic acute respiratory failure: a single-centre feasibility study. Intensive Care Med. 2012;38(10):1599–606.
45. Girault C, Bubenheim M, Abroug F, et al. Noninvasive ventilation and weaning in patients with chronic hypercapnic respiratory failure: a randomized multicenter trial. Am J Respir Crit Care Med. 2011;184(6):672–9.
46. Girault C, Daudenthun I, Chevron V, Tamion F, Leroy J, Bonmarchand G. Noninvasive ventilation as a systematic extubation and weaning technique in acute-on-chronic respiratory failure: a prospective, randomized controlled study. Am J Respir Crit Care Med. 1999; 160(1):86–92.