Weaning from mechanical ventilation

Deniz Öztekin, RN, PhD, Assistant Professor and Lecturer, Florence Nightingale School of Nursing, University of Istanbul, Turkey (✉)
Neriman Akyolcu, RN, PhD, Associate Professor, Florence Nightingale School of Nursing, University of Istanbul, Turkey

Seher Deniz Öztekin, Tepegöz sk. Martı Ap. A. Blok D: 8 Çiftehavuzlar, Göztepe, Kadıköy, Istanbul, Turkey.
e-mail: ioztekin@hotmail.com

INTRODUCTION

This article reviews the literature on the weaning process in relation to nursing care. Weaning is defined as the process of gradually reducing mechanical ventilatory support as the patient's own respiratory system recovers from disease (Keen, 2000). This process has been identified as one of the highest-ranked research priorities in nursing care by the American Association of Critical Care Nurses (ACCN) (Goodnough-Hanneman *et al.*, 1994).

The weaning process is different, both in terms of time and management, for patients who have been mechanically ventilated for a short time versus patients ventilated for a long time. In the literature, short-term mechanical ventilation is variously defined as between three and seven days. AACN's National Study Group on Weaning from Mechanical Ventilation defines 'short-term' conservatively, as three days or less (Goodnough-Hanneman *et al.*, 1994; Knebel *et al.*, 1994).

Increasingly, for patients with little chance of recovery, a decision to discontinue ventilation (terminal weaning) is part of treatment-limitation plans. Terminal weaning is also discussed below.

WEANING READINESS

Preweaning phase

Physiological and psychological readiness: Before active weaning can be considered, the precipitating events need to be addressed and complications (see below) prevented that might interfere with the weaning process (Knebel *et al.*, 1994).

Careful patient assessment is needed to decide which patients can be removed from the ventilator quickly, those that may require a prolonged weaning phase, and those not yet ready for discontinuing ventilatory support. The length of time a patient has been receiving mechanical ventilation is an important factor in this assessment. Generally, those receiving support for 72 hours or less can often be removed quickly from the ventilator (Goodnough-Hanneman *et al.*, 1994; McIntyre, 1995).

Burns' Wean Assessment Programmme (BWAP) helps to identify the status of haemodynamic parameters, hydration and nutrition, haematocrit, electrolyte levels and metabolic rate. Using a scoring system, BWAP assesses pain control, sleep/rest status, and the patient's level of anxiety and nervousness, as well as bowel problems, general body strength/endurance, improvement in chest radiograph, gas flow and work of breathing, airway clearance, respiratory strength and endurance, and arterial blood gases. For weaning to be considered, respiratory strength must be at least: negative inspiratory pressure (NIP) less than –20 mmHg; positive expiratory pressure (PEP) greater than +30 mmHg (Burns *et al.*, 1991).

Psychological criteria for weaning: The use of standard weaning criteria and indices help to evaluate physiological and psychological weaning readiness (Litwack, 1995; Yang and Tobin, 1991; Burns *et al.*, 1994; Woods *et al.*, 1995).

However, there is little published data to guide clinicians in the area of psychological readiness for weaning. Patient perceptions of mechanical ventilation have been reported as negative. They include descriptions of discomfort, activity restriction, lack of communication, anxiety, dyspnoea, fear, insecurity, and panic (Bergbom-Engberg and Haljamae, 1989; Burns *et al.*, 1991).

One study that examined communication/interaction between ventilated patients and nurses in critical care settings (Mentzel, 1994) verified that ventilated patients limit their communications: only 34 of the 217 observed interactions were initiated by patients in the study. Another study reviewed in the same paper (Mentzel, 1994) showed that the majority of interactions were initiated by nurses and were 'short term informative', that is, for the purpose of telling the patient what they were going to do. Nurses in this study were aware of alternative communication methods such as writing or using an alphabet or communication board for patients who could move but not speak; however , they almost never used them, relying instead on patient's gestures and attempts to mouth words.

As many as 47% of patients who spend more that five days in ICU may develop psychological disturbances. This may be due to the stress of critical illness, night-time sleep interruption, or the use of sedatives and other drugs. A competent, calm and efficient approach to nursing helps optimise the patient's environment, reduce patient depression and anxiety, and maximise communication (Goodnough-Hanneman, 1994; Burns *et al.*, 1995; McIntyre, 1995).

Environmental considerations that may improve the patient's sense of well-being include reducing extraneous noise, providing clocks, calendars, pictures, radio, television and if possible, a room with windows. Daily mobility should be considered. A method for the patient to communicate with staff and visitors should be devised. Use of a writing tablet, picture board or alphabet board may be useful (McIntyre, 1995).

Choice of weaning approach: The preweaning phase provides an opportunity to determine which approach is most appropriate for the patient. For example, multidisciplinary case management is the standard approach. However, if the patient in question is medically stable and has received mechanical ventilation for less than 24 hours, input from multiple experts may not be needed and may in fact delay weaning unnecessarily. In contrast, the multidisciplinary approach may be more appropriate for the patient on long-term ventilation, whose weaning process is more complex. Obviously, a care delivery system that produces the most positive patient outcomes while consuming the fewest resources is the desired goal (Gilligan and Raffin, 1996).

The physician decides when to begin gradually removing or 'weaning' the client from continuous mechanical ventilation (CMV). The decision is usually based on assessments made by nurses and respiratory therapists. The length of time required for succesful weaning is usually related to the underlying disease process and to the patient's state of health prior to mechanical ventilation (Esteban *et al.*, 1995; Cronin, 1997).

APPLICATION OF CLINICAL WEANING INDICES

Although there are many weaning indices, only a few have been adapted for clinical use, including standard weaning criteria (Litwack, 1995) and integrated weaning indices (Yang and Tobin, 1991). The criteria for a weaning trial are listed in Table 1, while the physiological criteria (Table 2) have been reported in Litwack (1995).

Integrated weaning indices

Pulmonary specific integrated weaning indices sometimes used are the frequency/tidal volume ratio (f/VT) and the Compliance, Rate, Oxygenation and Pressure (CROP) index.

A rapid shallow breathing pattern reflects an increased respiratory workload that may result in fatigue and finally failure. The f/VT ratio is calculated after the method of Yang and Tobin (1991) whereby the spontaneous respiratory frequency (f) in 1 minute is divided by tidal volume (VT) in litres. An f/VT value of less than 105 indicates weaning success; with a value of 105 or more indicating failure.

The CROP index is a good predictor of weaning success in many patients requiring mechanical ventilation (Burns *et al.*, 1995; Goodnough-Hanneman *et al.*, 1994; Hess, 1997). CROP provides a measure of pulmonary gas exchange and the balance between respiratory demand and respiratory muscle reserve (Yang and Tobin, 1991). A CROP index of 13 or more indicates weaning success, whereas an index of less 13 than indicates failure to wean (Yang and Tobin, 1991).

Table 1. Weaning criteria for a weaning trial

- Improvement, correction, or stabilisation of the active disease process
- Nutritional and fluid status sufficient to maintain the increased metabolic needs and demands of spontaneous respiration
- Adequate physical strength and mental alertness
- Afebrile status
- Stable cardiovascular, renal, and cerebral status
- Optimal levels of arterial blood gases, electrolytes, haemoglobin, and other laboratory tests

Table 2. Physiological criteria for a weaning trial (Litwack, 1995)

- Vital capacity (VC) ≥ 10–15 ml/kg
- Positive expiratory pressure ≥ +30 cm H_2O
- Maximum inspiratory pressure (negative inspiratory pressure) ≤ –20 cm H_2O
- Respiratory rate of ≤ 20 breaths per minute
- Fraction of inspired oxygen (FiO_2) < 50%, with 5 cm H_2O or less of PEEP
- Arterial oxygen level (PaO_2) > 60 mm Hg
- Minute ventilation (MV) ≤ 10 litres per minute
- Spontaneous tidal volume (STV) ≥ 5 ml/kg

Wean index

Burns *et al.* (1994) compared five weaning indices. They found that prediction was improved by combining the different indices into a Wean Index. Burns *et al.* (1994) reported bedside calculation of the Wean Index. A score of less than 4 was predictive of weaning success and greater than 4 of weaning failure. Burns *et al.* (1994) suggested it might be necessary to switch the patient briefly to assist/control mode to obtain these indices and emphasized a comprehensive approach to monitoring the progress of weaning patients and adjusting the plan of care. Prediction of weaning success is much better using a combination of pulmonary and general factors than when either is used separately.

WEANING PROCESS

In any discussion of mechanical ventilation, attention must be directed toward criteria for weaning and criteria for extubation (Litwack, 1995).

Choice of weaning method

The method of weaning usually involves either a T-piece, synchronised intermittent mandatory ventilation (SIMV), pressure support ventilation (PSV), continuous positive airway pressure (CPAP), or a combination of these. Questions about the appropriate weaning method arise (Knebel *et al.*, 1994). No single method can be universally recommended as the preferred method to discontinue ventilatory support for a given patient (Pierson, 1995). There is good evidence that T-piece trials can be more effective than IMV or PSV (Esteban, 1995).

However, there may be no single best weaning technique, and different patients may respond to different techniques. The best approach may be the method with which a clinician is most familiar (Pierson, 1995). Whatever approach is selected, it should be based on knowledge of the patient's condition and good clinical experience (Marini, 1995a; Pierson, 1995).

Patient explanation and reassurance

Before weaning is begun, the process should be explained to the patient. Since anxiety may affect how easy it is to wean the patient, it is important that the patient is given clear, concise information and reassured that all weaning attemps will be closely monitored (Ignatavicius and Varner-Bayne, 1991; Goodnough-Hanneman *et al.*, 1994; Burns *et al.*, 1995; McIntyre, 1995; Arnold, 1999).

Physiological criteria

The health care team must individualise the weaning process, considering the physiological comfort of the patient and variations in a method for weaning (Campbell, 1993). Weaning patients from mechanical ventilators is a gradual process. The ventilator settings are decreased incrementally. Arterial blood gases and respiratory status are assessed within 30 minutes to document the patient's response to change. The patient is eventually weaned to a CPAP of 5 cm. If at 30 minutes, the arterial blood gases are on, or near, the normal values, and if the respiratory rate is below 25 to 30 breaths per minute, the patient can be extubated (Cronin, 1997). The patient should then be given 40% oxygen by face mask.

T-piece trials

Weaning is usually accomplished through T-piece intermittent spontaneous breathing method or the IMV method. PSV is an alternative mode of weaning. In one major multicenter study, one or more daily trials of spontaneous breathing using a T-piece were three times faster to extubation than IMV and twice as fast as PSV (Esteban *et al*., 1995). In another study, T-piece trials were more effective than SIMV in weaning patients with quadriplegia (Peterson *et al*., 1994).

With the T-piece method, ventilatory support is periodically withdrawn and the patient is allowed to breathe spontaneously with supplementary, humidified oxygen. These spontaneous breathing periods are interspersed with periods of AMV, and gradually increased in duration, as the patient is able to sustain spontaneous ventilation (Marini, 1995a).

IMV and SIMV

IMV has been put forward since the early 1970s as a method to speed up weaning (Pierson, 1995). IMV and SIMV can be used to provide full or partial ventilatory support. With the IMV method, the patient is allowed to breathe spontaneously with periodic positive pressure breaths at a preset volume and rate. Weaning is achieved by gradually reducing the number of preset breaths given to the patient. The pressure support mode provides application of a low level of inspiratory pressure with every breath and the patient retains control of the cycle length and depth. This reduces the work of breathing for the patient to the extent that air-flow resistance as a result of the endotracheal tube and ventilator circuitry is offset.

In the SIMV mode, some patients may uncouple their breathing effort from the support provided by the machine. When this occurs, the patient continues to make spontaneous breathing efforts during the delivery of a 'machine breath' (Marini, 1995a). IMV or SIMV may be preferred over the pressure assist or control method for preventing respiratory alkalosis and reducing mean airway pressure (Burns *et al*., 1995; Hess, 1997).

With T-piece weaning, the percentage of ventilator-free time can be used to chart the patient's progress during weaning. The portion of a 24-hour period that the patient spends free from the ventilator is recorded. If the patient can spend a progressively greater portion of the day off the ventilator, weaning is progressing (Knebel *et al*., 1994).

EXTUBATION

Weaning and extubation are separate decisions (Sharar, 1995). The decision to extubate a patient, despite the existence of formal guidelines, is often based on the clinical judgement of a consultant anaesthetist. Most use the criteria for weaning from mechanical ventilation, but also take into account other criteria, such as the patient's ability to respond to verbal and physical commands, e.g. hand grasps or sustained head lift, and to maintain and protect the airway (Litwack, 1995). The features of successful extubation are listed in Table 3.

The decision to extubate should be based on assessment of adequate ventilatory function as predicted by standard weaning indices and the assessment of upper airway patency and protection. No single indicator will be 100% sensitive for predicting successful extubation (Sharar, 1995).

The argument against nurses extubating patients is based on the premise, 'if you cannot put it back, do not take it out'. The decision as to who will extubate the patient varies from unit to unit (Litwack, 1995). However, the literature emphasies the importance of a plan of nursing care that provides for the dynamic nature of the weaning process, and which is collaborative, systematic and comprehensive (Cohen *et al*., 1991; Cohen, 1994; Burns *et al*., 1991; Burns *et al*., 1995).

UNSUCCESSFUL WEANING ATTEMPTS

Use of the word 'failure' to describe the outcome of a weaning trial should be avoided as it can make both patient and care providers feel as if they have failed. The resulting 'failure mentality' can have adverse consequences on future weaning trials, undermine patient confidence, and discourage the bedside clinician. If weaning is described as a process of peaks and valleys, then continued ventilation after a weaning trial is not a failure but a natural part of the process (Knebel *et al*., 1994). An unsuccessful weaning attempt is usually due to an underlying pathological process that needs treatment (Marini, 1995a; Sharar, 1995).

Unsuccessful weaning may be due to various factors, as reported by Marini (1995a) and Sharar (1995), and summarised in Table 4.

If the first attempt at weaning is unsuccessful, it is important to determine the reasons and try to eliminate them in later attempts. Patients who require prolonged ventilatory support and extended periods of weaning often do best in settings that promote rehabilitation concepts. These patients will usually be transferred to subacute or extended care facilities (Cronin, 1997).

Table 3. Features of successful extubation

- Resolution of disease state or condition
- Haemodynamic instability
- Absence of sepsis
- Adequate oxygenation status on a decreased FiO_2 and decreased PEEP/CPAP
- Adequate ventilatory status and $PaCO_2$

Table 4. Contributory factors to weaning 'failure'

Description of problem	Factors
Oxygenation	▶ Decreased ventilation-perfusion ratio (V/Q) e.g. in asthma, emphysema, chronic bronchitis, bronchospasm ▶ Increased shunt e.g. atelectasis, pneumonia, acute respiratory distress syndrome (ARDS), pulmonary oedema ▶ Low venous oxygen (SvO_2) caused by increased oxygen extraction or reduced oxygen supply (or both)
Ventilation	▶ Central hypoventilation e.g. neurological injury, drugs ▶ Impaired neuromuscular function, increased dead space e.g. embolism, ARDS, emphysema ▶ Increased CO_2 production e.g. fever
Cardiovascular	▶ Left ventricular failure ▶ Haemodynamic instability

Unsuccessful weaning is usually due to an concurrent pathological process that needs treatment (Marini, 1995a; Sharar, 1995). The most common reason for failure to wean is an imbalance in the ratio between ventilation capacity and ventilation demand (Marini, 1995a). For many years, it has been clear to clinicians and investigators that various therapies may aid weaning of difficult-to-wean patients. These therapies include nutritional regimens, positioning, co-ordinating weaning with other interventions, ventilatory muscle training, pharmacological therapy, symptom management, biofeedback and relaxation, and environmental manipulation. Many of these interventions are based on observations and experience rather than on research findings (Gilligan and Raffin, 1996).

AVOIDANCE OF COMPLICATIONS

The healthcare team must individualise the weaning process, considering the physiological comfort of the patient and individual variations in a method for weaning (Campbell, 1993). Weaning is the process of going from ventilatory dependence to spontaneous breathing. The weaning process can be prolonged if the patient develops complications. Several authors have investigated these complications, such as pressure ulcers or malnutrition, barotrauma, subpleural air cysts, and emphasise the importance of skilful nursing care (Ignatavicius and Varner-Bayne, 1991; Reeves and Roux, 1999).

TERMINAL WEANING

Sometimes, it is evident that the patient will not complete the weaning process and that the final outcome may be either partial- or full-support ventilation. Some patients may have the resources and desire to continue with long-term mechanical ventilation in either a long-term care facility or at home. Other patients may prefer a terminal weaning process, i.e. one that allows for a humane death. Clear standards must be developed in order to provide structure and to guide clinicians through the process of ventilatory withdrawal during terminal weaning (Knebel *et al*., 1994; Reeves and Roux, 1999). For patients with little chance of recovery, a decision to discontinue ventilation (terminal weaning) is increasingly part of treatment-limitation plans. However, despite clear justification for the procedure, discontinuation of mechanical ventilation is a problematic treatment limitation for several reasons, especially since cessation of mechanical ventilation may precipitate death almost immediately (Freichels, 1993; Daly *et al*., 1996). Terminal weaning proceeds as vital signs deteriorate and the expected outcome is the death of the patient. As such, terminal weaning may take place when it is thought that there is very little likelihood of the patient's own respiratory system recovering (Goodnough-Hanneman *et al*., 1994).

Schneiderman and Spragg (1988) argue that there is no ethical basis for gradually weaning a patient unless the patient could be expected to adjust successfully to the withdrawal of mechanical ventilation. Daly and colleagues (1996) reported the results of the first study to address this problem directly. Specifically, their study provided a retrospective descriptive examination and comparison of the outcomes of rapid extubation and terminal weaning. They found that of thirty-three patients with endotracheal tubes, twenty-eight (85%) were simply extubated, with the remainder being terminally weaned. The researchers found no difference in the frequency of clinical signs of distress or in the duration of survival between the two groups. Nonetheless, Gilligan and Raffin (1996) remain concerned about the practice of simply extubating patients, because of the danger of causing severe air hunger and stridor.

Gilligan and Raffin (1996) reported a study by Wilson *et al*., investigating the administration of sedatives and analgesics during withholding and withdrawal of life support, and the method of ventilator withdrawal. Terminal weaning was done in 84 of 101 (83%) patients who had some form of limitation of life-supporting treatment. The usual method was to withdraw supplemental oxygen and PEEP first, and then to stop the ventilator and place the patient on a T-piece 'only if these actions did not result in death'. A study by Daly *et al*. (1996) indicated how abruptly ventilator parameters were changed or how much time elapsed between making ventilator changes, and deciding to stop mechanical ventilation completely and place the patient on a T-piece. It is unclear whether the nursing staff were consulted regarding the morality of these acts of ventilator withdrawal, or whether there was simply a widespread healthcare cultural belief in the appropriateness of treatment withdrawal in the context of poor quality of life or a terminal illness. In the same study by Gilligan and Raffin (1996), it was reported that, in two hospitals in San Francisco, USA, the most common practice was to discontinue supplemental oxygen and PEEP. If this did not lead to a quick death, the patients were placed on a T-piece .

Although concomitant administration of narcotics or sedatives is commonly recommended, debate about the moral justification for this continues. Even if certain about the moral correctness of treatment withdrawal, perceptions of the adequacy of sedation and analgesia are clearly important to the nurse's comfort in participating. This has implications for educating nurses about the expected clinical course of patients' terminal weaning, and for the nurse's participation in the plan for pharmacological management. Nurses should become involved in the decision to terminally wean and the method in which this is carried out (Daly *et al*., 1996; Keen 2000).

NURSING CARE OF THE MECHANICALLY VENTILATED PATIENT

Respiratory monitoring and breath sounds

The first goal of nursing care is monitoring. Respiratory rate and pattern are easy to monitor and may be the most reliable indicators of patient progress during weaning .Weaning may proceed as quickly as the patient's respiratory rate and subjective tolerance allow (McIntyre, 1995).

During the weaning process, the nurse should closely monitor dyspnoea, spontaneous minute volume and spontaneous tidal volume and the patient's ventilatory status (Marini, 1995a; Marini, 1995b). Respiratory monitoring includes taking vital signs, listening to breath sounds every 30 to 60 minutes initially, non-invasive respiratory monitoring (e.g. capnography, pulse oximetry), and checking arterial blood gas values. Continuous non-invasive monitoring provides the nurse with a means of guiding the patient's activities, such as weaning, physical or occupational therapy, and self-care. These activities can be paced so that oxygenation and ventilation are adequate (Ignatavicius and Varner-Bayne, 1991; Freichels, 1998). Vital signs change during episodes of hypercapnea and hypoxaemia. It is important for the nurse to note any precipitating causes and to correct them promptly.

The presence and description of breath sounds are assessed and recorded, including bilateral equal breath sounds to ensure proper tube placement. Respiratory secretions are observed for type, colour, amount and frequency. Patient comfort is an important factor in the weaning process. The area around the endotracheal tube or tracheostomy site should be assessed at least every four hours for colour, tenderness, skin irritation and drainage.

Oxygenation and arterial blood gas values

Interpretation of arterial blood gases is essential to allow the nurse to evaluate and suggest ventilator settings that help the patient. Although the physician usually prescribes specific ventilator changes, the nurse assesses and evaluates the patient's response to those changes. Since the nurse spends most time with the patient, the nurse is most likely to be first to recognise slight changes in the patient's vital signs, fatigue or distress, or changes in arterial blood gas values. The nurse should promptly confer with the physician and implement the appropriate interventions. Continuous pulse oximetry (SpO_2) monitoring is a sensitive indicator of oxygenation status during the weaning process.

During weaning , the nurse should perform arterial blood gas analysis for arterial oxygenation (PaO_2), arterial oxygen saturation (SaO_2), and calculation of oxygen delivery (CaO_2) (Ignatavicius and Varner-Bayne, 1991; Freichels, 1993).

Cardiovascular status

The nurse should monitor pulse, blood pressure, and cardiac rhythm to evaluate arrhythmias, tachycardia, bradycardia, or other abnormalities. If necessary, the patient should be returned to full ventilatory support. Silent myocardial ischaemia may occur in some postoperative patients during weaning (Stroetz and Hubmayr, 1995).

Communication

The nurse has a key role in supporting the psychological needs of the patient and family. Anxiety can play a major role in the tolerance of mechanical ventilation. Skilled and sensitive nursing care is needed to promote psychological well-being and to facilitate synchrony with the ventilator. Communication can be frustrating and anxiety-producing because the patient cannot speak. The patient and family may panic because they prematurely believe the patient has lost his or her voice. They must be reassured that the endotracheal tube prevents speech but that it is a temporary situation.

Alternative, creative methods of communication must be adapted to meet the patient's needs, including magic slates, writing paper, computers, and tracheostomy tubes that permit talking. Finding a non-stressful means of communication is important because patients often feel isolated and frustrated when they cannot speak. Anticipation of the patient's needs, easy access to familiar belongings, and a nursing call-light within reach are effective ways of giving the patient a sense of control over his environment. They also help by giving the patient some part in self-care (Ignatavicius and Varner-Bayne, 1991; Menzel, 1994; Goodnough-Hanneman *et al*., 1994; Burns *et al*., 1995; McIntyre, 1995; Arnold, 1999).

CONCLUSION

The purpose of this article was to clarify the process of weaning from mechanical ventilation, with the aim of promoting a common understanding of the weaning process. We have attempted to utilise research-based findings to develop clinical guidelines to assist clinicians and nurses caring for patients being weaned from mechanical ventilation, and so promote positive outcomes for these patients.

REFERENCES

Arnold E. (1999). Communicating with clients in stressful situations In: Arnold E, Underman Boggs K, (eds.), *Interpersonal Relationships*. Philadelphia: WB Saunders, 445–475.

Bergbom-Engberg I, Haljamae J. (1989). Assessment of patients' experience of discomforts during respiratory therapy. *Critical Care Medicine*; **17:** 1068–1072.

Burns SM, Barton D, Fahey S, Slack D. (1991.) Weaning from mechanical ventilation: a method for assessment and planning. *AACN Clin Issues Critical Care Nursing*; **2:** 372–387.

Burns SM, Burns JE, Truwit JH. (1994). Comparison of five clinical weaning indices. *American Journal of Critical Care*; **3:** 342–352.

Burns SM. (1995). Weaning from long-term mechanical ventilation. *American Journal of Critical Care*; **4:** 4–22.

Campbell ML (1993) Case studies in terminal weaning from mechanical ventilation. *American Journal of Critical Care*; **2:** 354–358.

Cohen IL. (1991). Reduction of duration and cost of mechanical ventilation in an intensive care unit by use of a ventilatory management team. *Critical Care Medicine*; **19:** 1278–1284.

Cohen IL. (1994). Weaning from mechanical ventilation: the team approach and beyond. *Intensive Care Medicine*; **20:** 317–318.

Cronin SN. (1997). Nursing care of clients with disorders of the lung parenchyma and pleura. In: Black JM, Matassarin-Jacobs E, (eds.), *Medical Surgical Nursing*. Philadelphia: WB Saunders, 1133–1187.

Daly BJ, Thomas D, Dyer MA. (1996). Procedures used in withdrawal of mechanical ventilation. *American Journal of Critical Care*; **5:** 331–338.

Esteban et al. (1995). A comparison of four methods of weaning patients from mechanical ventilation. *New England Journal of Medicine*; **332:** 345–350.

Freichels AT. (1993). Orchestrating the care of mechanically ventilated patients. *American Journal of Nursing*; **93:** 26–34.

Freichels AT. (1998). Managing mechanical ventilation in status asthmaticus. *Dimensions of Critical Care Nursing*; **17:** 2–10.

Gilligan TG, Raffin TA. (1996). How to withdraw mechanical ventilation: more studies are needed. *American Journal of Critical Care*; **5:** 323–325.

Goodnough-Hanneman SK *et al.* (1994). Weaning from short-term mechanical ventilation: a review. *American Journal of Critical Care*; **3:** 421–441.

Hess DR. (1997). Mechanical ventilation of the adult patient: initiation, management and weaning. In: Burton GG *et al*., (eds.), *Respiratory Care: A Guide to Clinical Practice*. Philadelphia: Lippincott, 611–641.

Ignatavicius DD, Varner Bayne M. (1991). *Medical Surgical Nursing*. Philadelphia: WB Saunders, 2028–2031.

Keen A. (2000). Critical incident: reflection on the process of terminal weaning *British Journal of Nursing*; **9:** 1059–1062.

Knebel AR, Shekleton M, Burns S, Clochesy J, Goodnough-Hanneman SK, Ingersoll GL. (1994). Weaning from mechanical ventilation: concept development. *American Journal of Critical Care*; **3:** 416–420.

Litwack K. (1995). *Postanesthesia Care Nursing*. St. Louis: Mosby Year Book, 409–415.

MacIntyre NR. (1995). Psychological factors in weaning from mechanical ventilatory support. *Respiratory Care*; **40:** 277–281.

Marini J. (1995a). Weaning techniques and protocols. *Respiratory Care*; **40:** 233–238.

Marini JJ. (1995b). Dyspnea during weaning. *Respiratory Care*; **40:** 271–276.

Menzel L. (1994). Need for communication-related research in mechanically ventilated patients. *American Journal of Critical Care*; **3:** 165–176.

Pierson DJ. (1995). Weaning from mechanical ventilation: why all the confusion? *Respiratory Care*; **40:** 228–232.

Peterson *et al.* (1994). Two methods of weaning persons with quadriplegia from mechanical ventilation. *Paraplegia*; **32:** 98–103.

Reeves CJ, Roux G. (1999). The lower respiratory system. In: Reeves CJ, Roux G, Lockhart R. (eds.), *Medical Surgical Nursing*. New York: McGraw Hill, 56.

Sharar S. (1995). Weaning and extubation are not the same. *Respiratory Care*; **40:** 239–243.

Schneiderman LJ, Spragg RG. (1988). Ethical decisions in discontinuing mechanical ventilation. *New England Journal of Medicine*; **318:** 984–988.

Stroetz RW, Hubmayr RD. (1995). Tidal volume maintenance during weaning with pressure support. *American Journal of Respiratory and Critical Care Medicine*; **152:** 1034–1040.

Wood G *et al.* (1995). Weaning from mechanical ventilation: physician directed *vs* a respiratory-therapist-directed protocol. *Respiratory Care*; **40:** 219–224.

Yang KL, Tobin MJ. (1991). A prospective study of indexes predicting the outcome of trials of weaning from mechanical ventilation. *New England Journal of Medicine*; **324:** 1445–1450.