Weaning from ventilation: a nurse-led protocol

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INTRODUCTION

This paper describes the process and outcome of developing a nurse-led weaning protocol within a busy intensive care unit (ICU), with six intensive-care beds and two high-dependency care beds. The unit is based in an acute National Health Service (NHS) hospital, in the south of England. It admits approximately 500 patients per year, including some children. Specialist spinal and burn injury units are also based at the hospital, so that, in addition to general intensive care patients, the unit also admits a significant number of patients with spinal problems and burn injuries.

Approximately 50% of the unit's admissions are intensive care patients, of whom 95% are ventilated. Based on our year 2000 data of ventilated patients, the mean number of ventilator days per ICU survivor was four days (SD 0.65) and five days (SD 0.58) for non-survivors.

Practice development team

A year ago, the ICU established a practice development team, known as the Radnor ICU Practice Development Team. The team was facilitated by an academic nurse practitioner.

Practice development teams are becoming more common in the UK, as a means of achieving nurse-led change. According to McCormack and Garbett, 2000 (cited Manley, 2000), the goals of a practice development team (PDT) are:

- To increase effectiveness in patient-centred care
- To enable the effectiveness of healthcare teams
- To transform nursing culture and context.

The practice development team consisted of nurses from all grades. Participation was voluntary. One of the first tasks for the team was to establish a list of priorities for nurse-led practice. Several practice issues were identified. The most pressing need was considered to be the development of a nurse-led weaning protocol.

The need for a nurse-led weaning protocol

At the time that the practice development team was set up, it was common practice in the Salisbury District Hospital ICU for nurses to take the decision themselves to make small changes in ventilation in relation to arterial blood gas analysis.

However, nurses felt their ability to make decisions to progress the weaning process was hampered by having to seek medical approval for each step taken to reduce ventilation, e.g. changing from mechanical ventilatory support to T-piece support. They often felt they had the clinical expertise to determine the next step on the basis of their clinical assessment of the patient, but were required to ratify it first with medical colleagues.

The nurses also recognised that not all nurses have the same level of practice knowledge and expertise, and that there is always some degree of risk of nursing practitioners acting in ignorance. It was therefore felt that a clinical guideline, supported by relevant education, was required to safeguard the process.

In addition, not all patients are the same. Some have very complex respiratory needs that are influenced by other organ failures. Such patients may fall outside a clinical protocol, requiring more expert clinical assessment by the whole multidisciplinary team.

REASONS FOR WEANING

Patients who require long-term ventilation have a mortality rate of 30–40% (Scheinhorn *et al.*, 1994). Intensive care is a costly service to provide. Prolonged ventilation may increase the risk of complications. Thus, reducing patients' length of stay in ICU, through timely weaning, is a cost-effective strategy. In addition, shorter ICU stays result in better use of available resources. Some studies have shown that using standardised approaches to weaning from mechanical ventilation can shorten the duration of ventilation (Norton, 2000). However, based on systematic review, there is a limited amount of evidence to suggest that nurse-led weaning reduces the ventilation time (Price, 2001).

Weaning is defined as the process of assisting patients to breathe spontaneously without mechanical ventilatory support (Knebel *et al.*, 1998). The aim of weaning is for the patient to contribute to the work of breathing from an early stage (Tobin and Alex, 1994). However, this can present a very challenging workload for the patient, since respiratory muscle atrophy begins 72–96 hours after full ventilation is commenced (MacIntyre, 1988).

Enabling the patient to breathe spontaneously, while remaining ventilated, can reduce the need for sedation and shorten the weaning process. It reduces the time spent in ICU, resulting in physical and psychological benefits (Jenkins, 1997). These include:

- Reduced risk of post-operative complications. The risk of ventilator-associated pneumonia appears to be related to duration of mechanical ventilation (Clochesy *et al.*, 1997).
- Earlier return to independence and resumption of normal daily activities.
- Promotion of rapid recovery and rehabilitation (Myers, 1985).
- Regaining a normal sleep pattern (Ashworth, 1987).
- Reduced levels of stress associated with being in ICU for both the patient and family (Clarke, 1984).
- Psychological boost to the patient's well-being, by leaving the ICU earlier and returning to a more normal environment.

The Intensive Care Society (2000) in the UK has recently published guidelines on when and how to wean. However there is still much controversy about the ideal procedure.

PSYCHOLOGICAL FACTORS AND WEANING

An illness that is severe enough to require mechanical ventilation intensifies not only the physical factors with which the patient must cope, but also the psychological factors (Logan and Jenny, 1997). Psychological factors include:

- anxiety
- disorientation
- loneliness
- sensory deprivation and overload
- distress caused by the inability to communicate
- pain
- fear of the unknown
- fear of dying.

Weaning from mechanical ventilation can intensify some of these factors. If the patient is not properly prepared and informed, uncertainty, fear and the inability to communicate this fear can lead to increased anxiety.

Anxiety may precipitate shortness of breath and a fear of death and abandonment, as devices are withdrawn or ventilatory support reduced. Anxiety and fear may cause further physical distress by stimulating the sympathetic nervous system to cause bronchoconstriction. This may result in increased airway resistance, work of breathing and oxygen demand.

Often, patients are initially frightened to breathe without the ventilator. The psychological transition from dependency upon it, to a desire to be free of its constraints, is an important time for the patient. It is a time that often requires skilled nursing care.

HOW WE DEVELOPED A NURSE-LED WEANING PROTOCOL

Having established the membership of the practice development team and our priorities, we set about our first task, which was developing the weaning protocol.

We followed the four-phase clinical problem-solving model of Rosenberg and Donald (1995):

1. Identify the clinical problem
2. Search the literature
3. Evaluate the literature
4. Determine a clinical strategy.

The whole group met approximately once every month. Smaller, task-orientated teams met more frequently. In this way, we developed an effective way of working together.

Identifying the clinical problem

The first task was to identify the clinical problem. We undertook this through a group process of reflective inquiry. What became clear to us was that we could not consider the process of weaning from mechanical ventilation in isolation. A more complete picture was required that began with assessment of the patient's readiness to wean. We concluded that there were five distinct stages in the weaning process:

- Assessment of the patient's readiness to wean
- Weaning from ventilation
- Assessment of patient readiness for extubation
- Observation and monitoring following extubation
- Re-intubation (potential).

Searching and evaluating the literature

We used the five stages identified in the weaning process, as the basis for our literature search strategy, and divided the workload equally among the team.

Our objective was to make sure that every stage of the weaning process in our protocol would be based on research evidence. For the most part, we achieved this objective. However, for some parts of the protocol, we needed to refer to our own clinical knowledge and experience, or to that of our medical colleagues.

What our literature search did highlight was the dearth of high-quality research evidence available to inform our practice. Some literature was quite old, and much of what we found was based on clinical opinion and experience. Randomised, controlled trials and systematic reviews were rare.

Assessment of readiness to wean

We developed a set of baseline criteria, from our review of the evidence, which supports nurses' assessment of the patient's readiness to wean (Table 1). For further reading related to this section, see Armstrong (1995), Beale (1994) and Norton (2000).

Before weaning is begun, there should be clinical evidence that the disease process is resolving. Lung injury is often the primary disease (e.g. chronic obstructive pulmonary disease (COPD) or pneumonia), or it may be secondary, as in multiple organ failure resulting from septicaemia.

Weaning will be unsuccessful if it is attempted before there has been adequate recovery of lung injury. Failure to wean is likely in these circumstances, due to hypoxia and respiratory muscle fatigue. PaO_2:FiO_2 (arterial oxygen: inspired oxygen ratio) and lung compliance are indicators of persistent lung disease. It is unwise to attempt weaning unless there is clear evidence that these variables are returning to normal.

Improvement on the chest X-ray and the return of normal

Table 1. Criteria for commencement of weaning from mechanical ventilation*

Criteria
The patient's underlying disease process is resolving (Cull and Inwood, 1999)
The patient is normothermic and adequately perfused
The patient's systolic blood pressure is >90 mmHg on minimal, or without, inotropic support. If patient is on inotropes, discuss weaning with medical colleague (Anderson and O'Brien, 1995)
The patient has satisfactory arterial blood gases: $PaCO_2$ <7 kPa, PaO_2 >10 kPa, FiO_2 <40% (Anderson and O'Brien, 1995). NB. Unless different values are agreed by medical colleagues
The patient's respiratory rate is <30 breaths per minute; airway pressure <30 cmH_2O; and PEEP <5 cmH_2O. The patient has no severe electrolyte or metabolic imbalance (Cull and Inwood, 1999)
The patient has no clinical evidence of bleeding, with Hb >8 g/dL (Anderson and O'Brien, 1995)
There are no neuromuscular blocking agents in progress

* FiO_2 = fraction of inspired oxygen; Hb = haemoglobin level; $PaCO_2$ = partial pressure of arterial carbon dioxide; PaO_2 = partial pressure of arterial oxygen; PEEP = positive end expiratory pressure

breath sounds are other indicators that the disease process is resolving.

Ensuring the patient has adequate pain control is an obvious necessity. However, opiates should be titrated accurately to minimise the risk of respiratory depression.

In the UK, it is primarily a matter of clinical judgement, supported by a range of clinical information rather than a particular set of absolute values, that determines the decision to commence weaning (Beale, 1994).

Pyrexia: Pyrexia increases the work of breathing, therefore the patient should ideally be normothermic before weaning commences. Cold patients utilise more energy to keep warm (increasing oxygen demand). Peripherally shut down patients may retain sedatives.

Cardiovascular status: Patients should be cardiovascularly stable prior to commencement of weaning. Returning to spontaneous ventilation may increase cardiac demand and has the potential to worsen an already poor cardiac function by increasing stress. Optimising cardiac function may, for example, require the use of angiotensin converting enzyme (ACE) inhibitors, diuretics or nitrates to offer patients with poor ventricular function the best chance of a successful weaning outcome. Such decisions should be made with medical colleagues. Inotropic support may mask cardiac deterioration due to weaning, and should ideally have ceased prior to commencement of weaning.

Arterial blood gas values: The arterial blood gas values given in Table 1 are ideal values. Different values may be agreed with medical staff, particularly for patients with diseases such as COPD. Carbon dioxide (CO_2) monitoring is useful in patients with normal lung physiology, but it may be of limited value in patients with chronic lung conditions. Nurses should also be aware of metabolic conditions, which may compromise patients. For example, diuretic use in a COPD patient may cause a metabolic alkalosis, which in turn may reduce the respiratory drive.

Our guidelines state that the patient should be normopnoeic, as asynchronous breathing patterns and tachypnoea are signs of distress, particularly when the cardiovascular system is compromised.

Electrolyte balance: The management of electrolyte balance necessitates the consideration of feeding. Adequate nutrition and supplementary minerals are vital to provide energy for weaning. Inadequate nutrition can lead to breakdown of respiratory muscles.

Electrolyte imbalance can inhibit diaphragmatic breathing. Excessive carbohydrates and development of septicaemia may increase respiratory drive. Reduced phosphate levels may affect haemoglobin release of oxygen and low magnesium levels may impair cardiac function.

Bleeding: This may result in cardiovascular instability, resulting in poor oxygen delivery. A haemoglobin level of at least 8 g/dL should be ensured. Higher than normal levels of haemoglobin increase the viscosity of blood resulting in reduced capillary blood flow and poor tissue oxygenation. COPD patients may require a higher haemoglobin level to optimise oxygen transport.

Neurological status: A reduced neurological status may not necessarily prevent a patient from being weaned. If all other criteria have been met, then weaning can usually begin. Patients who have no pre-existing respiratory disease normally have an adequate respiratory drive, even though they are not fully conscious.

Cessation of sedation is desirable, prior to starting weaning. However, its presence is not an absolute contraindication, and some patients may require background sedation to help keep them comfortable.

Neuromuscular blocking agents should be stopped before weaning. Most agents have a relatively short half-life and weaning can begin soon after their cessation. However, if the nurse is unsure whether their effect has been negated, nerve conduction should be tested with a nerve stimulator.

Weaning from mechanical ventilation and readiness for extubation

The protocol that we developed covers the second and third stages of the weaning process. These are weaning from mechanical ventilatory support and assessment of readiness for extubation (Figure 1).

The protocol is designed to assist the nurse in her decision-making process. It may also be used to monitor and improve the quality of care. Potentially, it should reduce costs. It is part of a package of information, which includes guidelines for its use.

There are some important points that should be considered during the weaning process (Table 2).

The protocol was developed according to our evaluation of the best available evidence (Table 3). There are some parameters, which we have used, that were reported in the literature for which no references were given to support them. However, we have accepted their validity on the basis of the clinical expertise of the authors. Other parts of the protocol, as stated above, are based on our own experience.

Patient factors: Clearly, no two patients are the same and the speed and success of weaning will vary. The nurse will need to take into account the length of time the patient has spent ventilated, loss of nerve supply to respiratory muscles including polyneuropathy associated with critical illness, lung pathology and whether there is a chronic respiratory history.

Because each patient is unique and will respond according to what is 'normal' for him, the nurse looking after him must use her own clinical judgement in relation to her ongoing observation and assessment. She should refer to a senior nurse or medical colleague if further guidance is required.

Spinal injuries: In our ICU we admit patients with high spinal injuries. They require a different weaning protocol due to

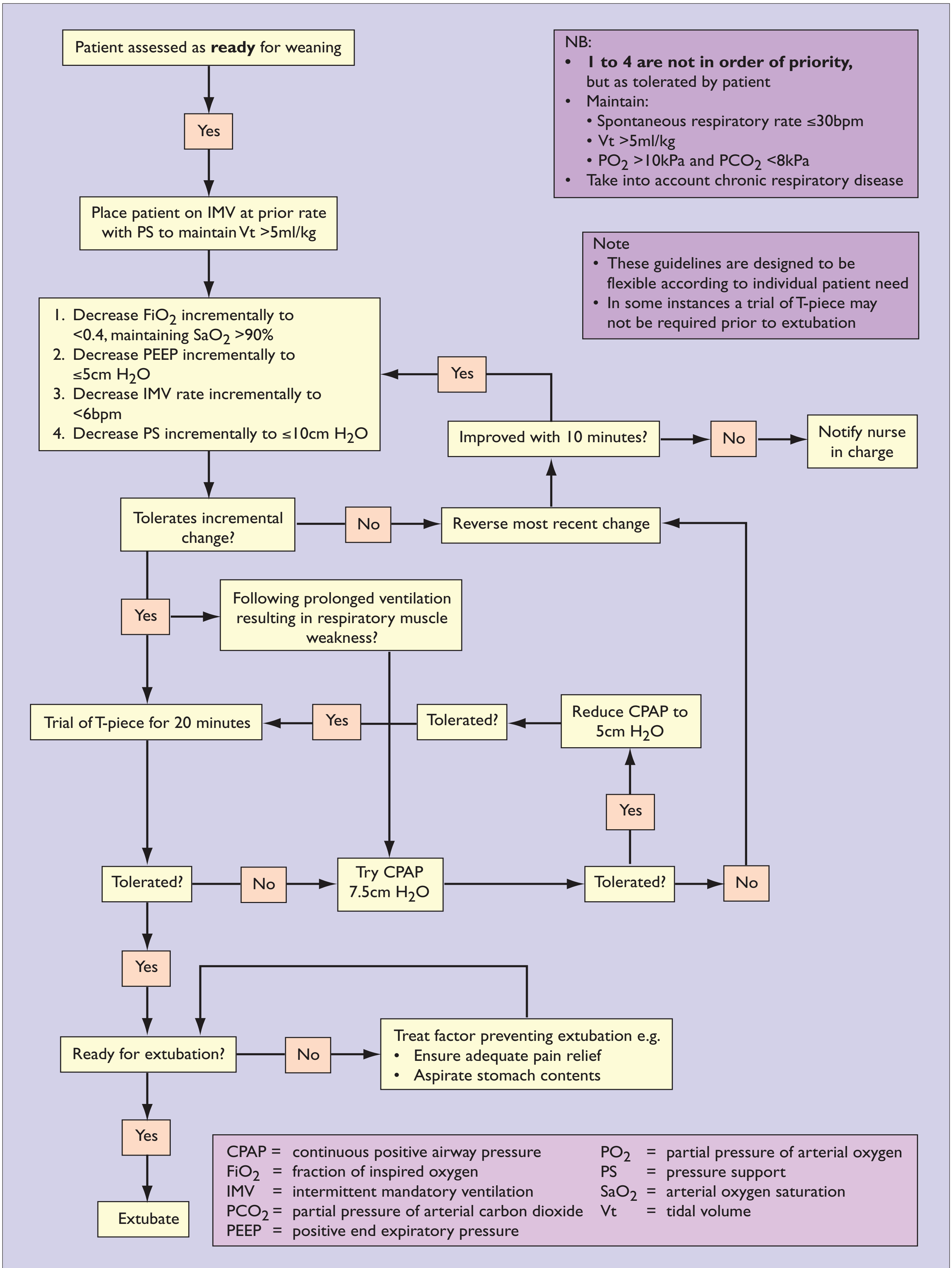

Figure 1. Nurse-led weaning protocol.

Table 2. Points to consider during the weaning process

- A metabolic alkalosis can inhibit respiratory drive and an acidosis will increase ventilatory drive. (Hanneman, 1999)
- Adequate nutrition and supplementary minerals are vital to provide energy for weaning (Armstrong, 1995; Grossbach-Landis, 1983). Inadequate nutrition can lead to the breakdown of the respiratory muscles, and electrolyte disorders. Phosphate is important for muscle work; its depletion may lead to diaphragmatic weakness. Excessive carbohydrates may lead to hypercapnia and increased ventilatory drive (Hanneman, 1990)
- Abdominal distention due to ileus, flatus or constipation can produce diaphragmatic tamponade (Hadfield, 1999)
- Maintain haemoglobin above 10 g/dL in patients with chronic obstructive pulmonary disease to maintain oxygen-carrying capacity (Henneman, 1990)
- Treat pyrexia above 38°C and shivering, as both these features may increase oxygen consumption (Manthous *et al.*, 1995)
- Patient comfort may minimise the need for analgesia, which can depress the respiratory drive. Careful positioning will optimise patient comfort
- Adequate pain control is a priority, as pain will increase respiratory rate and may increase oxygen consumption
- Adequate rest and sleep must be planned for. Increased ventilatory support may be required overnight, to allow the patient to rest

Table 3. Sources of evidence associated with specific parameters in the protocol*

- For respiratory rate >35 breaths per minute, as a sign of distress
- Haemoglobin saturation <90%
- Heart rate >140 bpm
- Able to clear secretions
- Ventilator rate weaned to >6 breaths per minute
- Respiratory rate ≤25 breaths per minute while ventilated, as a sign of no distress
- PEEP ≥5 cmH_2O
- 10-minute time period to see improvement following reversal of the most recent weaning change
- Trial of T-piece

Esteban *et al.* (1995)

- Decrease oxygen delivery to >50%
- PaO_2 >10 kPa
- $PaCO_2$ <7 kPa
- Respiratory rate below 30 breaths per minute

Anderson and O'Brien (1995)

- Tidal volume = 5 ml per kg

Dreyfuss *et al.* (1988)

- Underlying disease process is resolving
- No severe electrolyte or metabolic imbalance

Cull and Inwood (1999)

- Normally, pressure support is not weaned below 10 cm H2O. Below this point, the positive pressure does not overcome the resistance of the ventilator circuit, humidifier and endotracheal tube. Therefore, further reduction below this level may increase the work of breathing.

Bernstein *et al.* (1993); Nathan *et al.* (1993)

kPA = kilopascal (unit of pressure); $PaCO_2$ = partial pressure of arterial carbon dioxide; PaO_2 = partial pressure of arterial oxygen; PEEP = positive end-expiratory pressure.

respiratory nerve blockade and the necessity for diaphragmatic breathing. Such patients are normally weaned onto biphasic airway pressure (BiPAP) prior to discharge to the spinal unit.

Burn injuries: Our burn-injured patients often require frequent admissions to theatre for dressing changes and skin grafting. They are often ventilated for a long time and can present a difficult weaning challenge. In patients with an inhalation injury, it is advisable to check for airway oedema before beginning weaning.

Patient monitoring: The patient should be observed throughout the weaning process and after extubation for any signs of respiratory distress so that any underlying cause may be treated. Some patients may need to be returned to a period of increased ventilatory support on several occasions, e.g. overnight, so that they do not become over-tired. In our experience, some patients have become over-tired. It is therefore important to plan adequate rest and sleep periods as part of the weaning process.

Assessment of readiness for extubation

The patient is considered ready for extubation when the weaning process is complete (Figure 1). If there has been any physiological deterioration, proceeding to extubation is extremely unwise. Conscious level is the most obvious deterioration.

The patient must be able to maintain an airway, cough, and clear secretions. Sometimes, if coughing is poor, secretions are copious.

If the patient is non-compliant, a mini-tracheostomy should be considered. Long-term ventilated patients and those with chronic respiratory disease will often require a full tracheostomy before weaning is begun.

Observation and monitoring following extubation

The aim of post-extubation observation is to monitor the patient closely, so that early intervention can be carried out. If a patient deteriorates to the extent that respiratory failure occurs, then it is a failure on our part that we have not recognised the signs of deterioration early enough. The importance of vigilant monitoring cannot be overstated. For further reading in this area, please see Becker and Ellstrom (1997), Hudak *et al.* (1990) and Simonds (1993).

Observation and monitoring can be considered from a systems point of view. Obviously, the respiratory system is the most important to monitor. However, this should not be done at the expense of the other systems.

Respiratory observation and monitoring: The rate, depth and rhythm of breathing should be monitored.

When hypoxaemia or hypercapnia occurs, the respiratory centre responds by increasing respiratory rate and depth. Patients with respiratory acidosis have rapid shallow respiration which may be caused by airway obstruction, possibly due to retained secretions, laryngeal spasm or lung disease.

Hyperventilation may be an indicator of anxiety or pain and may lead to respiratory alkalosis. Metabolic acidosis is characterised by an increase in rate of breathing and conversely, a severe metabolic alkalosis may reduce the respiratory drive resulting in slow, shallow breaths. Kussmaul's breathing – often seen in diabetic ketoacidosis and renal failure – is characterised by a slow rate with deep breaths.

An increase in respiratory rate of as little as two breaths per minute above the patient's normal may be significant and treatment may need to be commenced immediately. As the respiratory rate increases the work of breathing will become very tiring and will eventually lead to exhaustion requiring ventilation. This may take minutes or hours depending upon the patient's reserves. There are several important signs of laboured breathing, including:

- Flaring of the nostrils.
- Pursing of the lips on exhalation to increase auto-PEEP.
- As respiratory failure worsens, use of the accessory muscles of breathing may occur. Intercostal retraction may be seen, i.e. sucking in of the muscles and skin be-

- tween the ribs and above the clavicles and sternum during inspiration.
- Patients with COPD often prop themselves up on outstretched arms to improve chest expansion.

Breath sounds are an important source of information.

- Listening to the chest with the diaphragm of the stethoscope may reveal absent breath sounds over the affected part of the lung and can be caused by pneumothorax or pleural effusion.
- Diminished breath sounds, i.e. poor airflow to an area of lung, can be caused by emphysema or pleural effusion.
- Bronchial sounds are normal when heard over the trachea. When they are heard in the peripheral lung fields, they indicate an area of consolidation (e.g. pneumonia).
- Fine crackles are light continuous sounds heard as small airways are reopened or re-inflated during end inspiration. They can occur in pneumonia and congestive heart failure. Coarse crackles are rumbling low-pitched sounds that occur with pneumonia, asthma and bronchitis.
- Wheezing is a high-pitched squeaky whistling sound produced by the passage of air through narrowing bronchi as in asthma or bronchospasm. The wheeze is superimposed on the expiratory phase. Wheezes heard during inspiration are often due to secretions in the large bronchi and may disappear or become less numerous after coughing.
- Pleural friction rub is a creaking coarse sound heard when inflamed and roughened pleura rub against each other and can be due to pleurisy or pleural effusion.
- Stridor is a loud crowing sound heard during inspiration. A foreign body, laryngeal spasm or exudate related to infection, can produce it.

The patient may become dyspnoeic following extubation, i.e. they have difficulty in breathing or shortness of breath. This can be very frightening, causing distress, which in turn compromises the respiratory status. A calm, supportive attitude and kind words can be very effective in reassuring an anxious patient. There is nothing more frightening than not being able to breathe (Todres *et al*., 2000).

Central cyanosis is a serious sign of poor respiration. It is noted on the tongue and lips when the patient has a low PO_2.

Other observations: When respiration is compromised and oxygen levels fall, the sympathetic nervous system usually compensates by increasing the heart rate and constricting blood vessels in an effort to improve cardiac output. The patient's skin may become cool, pale and clammy. Eventually, as myocardial oxygenation diminishes, blood pressure and cardiac output fall and changes in heart rate occur. Cardiac arrhythmias may develop. A severe hypoxic episode may result in bradycardia, and can occur very suddenly in infants.

Small changes in oxygen delivery to the brain, and a rise in arterial carbon dioxide levels can affect brain function and the patient's behaviour. Initially, cerebral hypoxia causes anxiety and restlessness, which leads to confusion, agitation and lethargy. The primary sign of hypercapnia is headache and occurs as a result of cerebral vessels dilating in an effort to increase the blood supply to the brain. Classically, severe hypercapnia is characterised by a 'cherry red' facial complexion. If carbon dioxide levels continue to rise, the patient is at risk of seizure and coma.

The nurse should know the signs of respiratory distress and observe for them throughout the weaning process, initiating treatment to correct underlying respiratory problems and associated alterations in the acid-base balance. Regular chest physiotherapy, postural drainage and pharyngeal suction may be required to improve respiratory status.

Pain: This should be treated promptly with effective use of analgesia. Whenever possible, non-opiate drugs, that do not reduce respiratory drive, should be given. Particular attention should be given to the pain felt by patients following abdominal and thoracic surgery. If necessary, an epidural should be inserted prior to commencement of weaning. Optimal patient positioning can make a lot of difference; diaphragmatic excursion should be optimised.

Re-intubation

Assessment of the need for re-intubation is based on the deteriorating patient's condition, in relation to:

- Respiratory function
- Cardiovascular status
- Level of consciousness.

Specific criteria for re-intubation are not particularly helpful, as each patient will have a different reserve in relation to the work of breathing and a varying tolerance to levels of oxygen and carbon dioxide. However, adequate minute ventilation is an important factor, which can be estimated from the patient's minute volume; measured using a Wright's spirometer.

CONCLUSIONS

Patients who require long-term ventilation have a high mortality rate and intensive care is a costly service to provide. Standardised approaches to weaning from ventilation may reduce the length of stay of patients in intensive care, which in turn may reduce the risk of complications.

Following the inception of the Radnor ICU Practice Development Team in Salisbury, UK, the decision was made to develop a unit protocol for nurse-led weaning. The protocol is presented in this paper. It is designed as a guide to assist the nurse in the decision-making process, and is based on an evaluation of the best evidence available to us at the time. Since no two patients are the same, the speed and success of weaning will vary. Thus, the aim of the protocol is to assist nurses in making clinical decisions. It does not provide strict *rules* for practice.

The protocol is based on evidence from the literature and our own experience. We believe it is sufficient to guide nurses through the weaning process for the majority of our patients.

Weaning success is usually described as the ability to maintain spontaneous ventilation for 24 hours following withdrawal of ventilatory support. Failure is a term often poorly defined, making comparison of different methods of weaning difficult. Specific criteria are not altogether helpful, as each patient will have a different tolerance. 'Failure' is also a very negative term, which can have a demoralising effect on patients. It is a term to be avoided when making a weaning 'contract' with a conscious patient.

We are in the process of evaluating our weaning protocol. As with all innovations, it is likely that we can make improvements to it. In the meantime, we are pleased to share our development with an international audience and look forward to receiving comments from other nurses.

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