Immediate postoperative evaluation of the patient remains a crucial role of the intensivist. Postoperative patients can be divided into the otherwise healthy, chronically ill, and acutely ill for strategizing about care. For chronically ill and acutely ill patients who require ongoing ventilation, ventilator management continues to evolve toward modes that are more interactive with patient needs. Newer modes of ventilation are also being explored to protect the lung against damage attributable to mechanical ventilation. Weaning indexes and associated protocols have become more sophisticated and now allow physicians greater certainty in evaluating patients’ readiness for extubation. This article will discuss factors to be considered prior to extubation as well as the latest ventilatory and weaning strategies.

Over the past decade, our understanding of both the physiology of the postoperative state and ventilator technology have advanced dramatically. Evaluation of the postoperative patient is now more sophisticated. New modes of ventilation have appeared. Intensivists have also developed strategies to assess patients’ abilities to be extubated more promptly. This article will review the various factors involved in patient evaluation, postoperative ventilator management, weaning, and extubation.

**Evaluation of the Postoperative Patient**

Postoperative patients can be classified into several groups: otherwise healthy, chronically ill, and critically ill patients. The otherwise healthy patient is usually extubated in the operating room (OR) unless there was an unexpected difficult intubation, fluid overload and an edematous airway, a long intraoperative course, or the administration of excessive sedation or paralysis. In these situations, the otherwise healthy patient may require a short course of postoperative ventilation. The chronically ill patient may have COPD, cardiac disease, or a neuromuscular problem that makes immediate postoperative extubation inadvisable. The critically ill patient with sepsis or ARDS may be intubated prior to operation and returns to the ICU intubated for continued treatment.1

On arrival from the OR, an appropriate “signout” to ICU or postanesthesia personnel is made, including preoperative laboratory results, intraoperative fluid management, and anesthetic technique. An assessment of the likelihood of severe pain, and strategy for its control are devised. After this brief report is given, a systematic approach should be undertaken in the review of patient status prior to considering weaning.1

**Vital Signs and Hemodynamic Parameters**

**Temperature:** Patients, on average, sustain a core temperature drop of 2 to 3°C in the OR. This is attributable largely to exposure to a cold environment and impaired thermoregulation.2 Within the OR, heat is lost by conduction, convection, and radiation. IV fluids, if not warmed, contribute to heat loss. Normally, thermoregulation controls core temperature within 0.2°C; anesthetics widen the interthreshold homeostatic range 20-fold, so that poikilothermia exists over an approximately 4°C range.2 By reducing tonic thermoregulatory vasoconstriction, anesthetics permit shift of heat to the periphery and a temperature drop of 1 to 1.5°C in the first hour of anesthesia. Radiation and convection of heat to the environment then occur in a linear fashion, with 90% of the heat loss through the skin. Anesthetics and paralysis also prevent shivering intraoperatively, a protective mechanism.

Postoperatively, hypothermia causes decreased tissue perfusion via vasoconstriction. This results occasionally in a postoperative metabolic acidosis. Postoperative shivering induced by the hypothermia can be hazardous3 in some patients because of increased oxygen consumption and CO2 production as high as 200 to 300% of normal. This may result in myocardial ischemia and hypercapnic ventilatory failure.1 Ablation of shivering is associated with decreased metabolic demands and myocardial work.3 Meperidine is often useful in ablating shivering while active
rewarming takes place. A core temperature of 36 to 38°C is desirable prior to extubation.

BP, Heart Rate, and Hemodynamic Parameters: Hemodynamic stability is obviously desirable prior to extubation. Tachycardia postoperatively usually is an indication of pain, an awake but paralyzed state, hypovolemia, or anxiety. Intraoperative fluid is clearly a major consideration, but intraoperative positioning in the Trendelenberg posture may result in airway edema independent of total fluid balance. Patients with extensive surgery, particularly vascular and retroperitoneal surgery, frequently extravasate fluids for 24 to 48 h so that early extubation is undesirable until fluid balance is achieved. If the patient arrives from the OR with a central line, at least one measurement of central venous pressure or pulmonary artery occlusion pressure should be determined. Although there is controversy currently regarding the risk to benefit relationship of right heart catheterization, most intensivists find measurement of central pressures valuable in fluid resuscitation decisions.

Physical Examination

Extubation in the recovery room is performed when the patient has awakened sufficiently, is able to respond to commands, and has regained sufficient strength to protect his/her airway. Paulin et al studied healthy volunteers and assessed four parameters (swallowing ability, vocal cord approximation, airway patency, and mandible elevation) to correlate the ability to protect the airway with the maximum inspiratory pressure (MIP). The MIP is commonly assessed as an extubation parameter because it correlates with diaphragmatic strength and the ability to ventilate. The diaphragm uniquely resists curarization and is the last muscle to become paralyzed during an anesthetic, as well as the first to recover from neuromuscular blockade. After paralysis, diaphragmatic strength returns prior to upper airway muscle strength and attendant airway protection. Paulin et al found that patients who were able to perform a 5-s head lift or leg lift were also able to perform all four airway protection tests. At this time, they also had an approximate MIP of −50 cm H₂O. Therefore, in clinical practice, the 5-s head lift or leg lift is used as a measure of patient ability to maintain an adequate airway.

If the patient is restless, extubation may be delayed to search for the cause. Restlessness can be due to hypoxemia, hypercarbia, or an impending disaster (ie, sepsis). In general, neurologic assessment is required to ensure that the patient is alert and has the strength to cough and clear secretions, as well as deep breathe. Often psychiatric issues such as preoperative anxiety level must be considered. Postoperative pain has been shown to correlate with preoperative anxiety. The presence of pain may preclude extubation because of splinting. If possible, pain should be controlled prior to weaning sedation.

History

For chronically ill patients with a history of prior prolonged intubation, it is important to consider physiologic variables that may condition outcome. These patients are unlikely to be extubated in the OR unless the surgery was unusually short and uncomplicated. Aside from the other usual problems such as metabolic derangements and nutritional deficits, the following problems pose risks for preventing successful extubation.

Chronic Lung Disease: Preoperative pulmonary function (PFT) test results in patients with chronic lung disease are helpful in assessing the probability of achieving successful early extubation. These should also be performed in patients with neuromuscular disease, chest wall and spinal deformities, and in the morbidly obese. Knowledge of PFT results allows optimal ventilator settings postoperatively and predicts success in extubation following lung resection.

Barisione et al found that preoperative pulmonary hyperinflation, as evidenced by an increased preoperative residual volume, was the most important functional parameter in predicting postoperative pulmonary complications. In addition, preoperative FEV₁ and diffusing capacity for carbon monoxide were also highly predictive of postoperative pulmonary complications. Mitchell et al, however, determined that PaO₂, PaCO₂, and spirometric measurements were not useful in predicting the incidence of postoperative pulmonary complications in asthmatics or in smokers with COPD. Preoperative excessive sputum production was associated with an increased risk of complications in both groups’ studies.

Patients with obstructive disease undergoing laryngoscopy and intubation may experience severe bronchospasm due to vagal nociceptive receptors. One strategy in problematic cases is to perform extubation while the patient is adequately anesthetized before the protective bronchodilatory effects of the volatile anesthetics have worn off. In patients with marked obstruction who require ventilation, the ventilator rate should be low enough to allow adequate expiratory time to prevent dynamic hyperinflation. Flow rates, tidal volumes, and expiration should be regulated to maintain peak airway pressures below 35 to 40 cm H₂O to protect against barotrauma.
In patients with restrictive disease, lung or chest wall compliance is decreased. Ventilator settings of low volumes and high rates replicate the pattern of ventilation that patients with restrictive disease normally assume. In addition, general anesthesia can be detrimental since it decreases functional residual capacity (FRC) by an additional 5 to 10%; FRC also decreases simply from lying in a supine position by 10 to 15% even in the healthy, spontaneously breathing patient. Abdominal surgical procedures have the highest incidence of postoperative pulmonary complications, as improvement in FRC usually requires 3 to 7 days. In patients with restrictive disease requiring ventilation, positive end-expiratory pressure (PEEP) should be instituted postoperatively to increase FRC toward normal,12 to avoid atelectasis and pneumonia.13

Neuromuscular Disorders: Nates et al14 classified acute weakness in critically ill patients into four groups: myopathy, neuromuscular junction abnormalities, neuropathy, and polynuromyopathy. Each of these may play a role in the postoperative state; of particular interest in postoperative weaning are the effects of anesthetic drugs, presence of preoperative neuromuscular disorders, and the potential for critical illness polyneuropathy.

Drugs and metabolic abnormalities postoperatively commonly influence muscle strength. Protracted elevated blood levels of paralytics and steroids cause upregulation of acetylcholine receptors at the motor endplate.15 Other drugs such as local anesthetics and antibiotics block the sodium channel in the acetylcholine receptor and prevent access to acetylcholine by the same mechanism as nondepolarizing neuromuscular blockers.16 Hypocalcemia and hypermagnesemia also potentiate the action of neuromuscular blockers. In the case of depolarizing relaxants such as succinylcholine, the possibility of pseudocholinesterase deficiency (1:2,500) must also be considered.17

Recently, Witt et al18 drew attention to the difficulty in weaning patients who have survived sepsis and multiple organ failure attributable to neuropathy of the neuromuscular components of the respiratory system. It is known by electrophysiologic studies that sepsis can cause a “critical illness polyneuropathy,” characterized by degeneration of axons of motor and sensory nerve fibers.19

Cough is also quite important in neuromuscular disease. Bach and Saporito20 have shown that successful weaning and maintenance of the airway in the case of neuromuscular disease may depend on the achievement of peak cough flows of at least 160 L/min.

Gender: Epstein and Ciubotaru21 found women to have an increased rapid shallow breathing index (RSBI, see below), but 80% were nevertheless extubated successfully. Smaller endotracheal tubes (< 7.0) were particularly confounding.21 There may be gender differences in response to the site of operation as well. Barisone et al10 found the male:female ratio of postoperative pulmonary complications in upper abdominal procedures to be 0.86. Differences in smoking history did not account for this difference.10

Age: Marx et al22 showed that increased age, if considered by itself, impacts greatly on postoperative mortality. Most of this impact may be attributable to coexisting age-related morbidity. Mircea et al23 found that age increased the chances of postoperative pulmonary complications, with a pulmonary complication rate of 49% in patients > 70 years. Mitchell et al,11 however, did not find age to be a factor in increasing the incidence of postoperative pulmonary complications.

Obesity: An otherwise healthy, obese person may have normal results of PFTs, but FRC and particularly the expiratory reserve volume decrease with weight, eventuating in tidal volumes impinging on the closing capacity, with consequent ventilation-perfusion mismatching in dependent zones.24 Mircea et al23 found that obese patients after cholecystectomy had a pulmonary complication rate three times as high (35%) as patients of normal weight. In abdominal surgical and thoracic cases, there is a high incidence of respiratory complications in the obese, especially in those with a history of obesity hypoxemia, and related to the closing capacity of the lungs. Hypoxia in the obese tends to persist for 4 to 6 days postoperatively. This can be minimized with intermittent lung inflation and with upright positioning. Regional pain management may help prevent postoperative pulmonary complications as well.24

Type of Surgery and Anesthesia

Operations on the upper abdomen and thorax are more likely to result in postoperative pulmonary complications, largely due to splinting from pain and the inability to take a deep breath. Upper abdominal surgery also affects diaphragmatic function, causing reductions in FVC and peak flows by 50% and a reduction in FRC by as much as 70%.10,25 This diaphragmatic dysfunction is not due to decreased contractility, but possibly to reflexes from the chest wall or peritoneum that may inhibit phrenic nerve function.25 Mitchell et al11 found that the duration of anesthesia, as well as the use of nasogastric intubation, significantly increased the risk of developing postoperative pulmonary complications.
**Drugs Administered**

There are several mechanisms for drug-induced postoperative respiratory depression. These include presynaptic neurotransmitter release, postsynaptic receptor blockade, combined presynaptic and postsynaptic receptor blockade, and interference with muscle-membrane conductance. These are detailed in Table 1.

**Modes of Ventilation—Which To Use**

All of the considerations above play into the decision about whether to extubate promptly. If ventilation postoperatively is required, a ventilatory mode must be selected. Table 2 describes currently used modes of ventilation. For otherwise healthy postoperative patients recovering from anesthesia and surgical trauma, the most commonly employed mode is intermittent mandatory ventilation (IMV) with low levels (5 to 8 cm H2O) of pressure support and PEEP. For chronically ill patients with underlying disease, the inspiratory flow rate, rate of ventilation, and inspiratory to expiratory (I:E) ratio are optimized for the underlying disease state. Patients with obstructive disease should be ventilated with a low rate and adequately low I:E ratio to permit full expiration; patients with restrictive disease benefit from higher rate, lower tidal volume, and higher I:E ratio.

In patients with acute lung injury postoperatively, recent interest has centered on the size of the tidal volume and the selection of PEEP level. CT scans of the lungs of patients in ICUs have highlighted regional differences in lung inflation and the potential overinflation of nondependent lung segments. Evaluation of the pressure-volume curves of patients receiving mechanical ventilation similarly suggests conventional tidal volumes of 10 mL/kg and PEEP levels of 10 may overinflate the lung, so that the lung is above the volume where it is still reasonably distensible (“upper inflection point” of the pressure volume curve). Parallel evidence raises the question of whether this causes lung injury, i.e., “volutrauma.” Very low lung volumes, however, may cause shear stress as closed alveolar units are repetitively opened with each tidal volume. A preliminary controlled trial of lower tidal volumes (6 mL/kg) and PEEP adjusted to that level of the pressure volume curve where compliance begins to be optimal (“lower inflection point”) suggests that this may improve prognosis. This kind of approach has been termed a “lung protective ventilatory strategy.” Currently the American College of Chest Physicians suggests an upper limit of plateau pressure at 35 cm H2O, but even this level may be too high, by some estimates, to avoid volutrauma. Ongoing trials will settle this issue, but for now, there is a distinct trend in US ICUs toward lower tidal volume ventilation and PEEP levels being sufficiently high to keep the lung “open” to avoid shear stress.

The other major trend in modes of ventilation is movement toward more interactive modes or ones in which the ventilator responds to the patient’s efforts and capabilities. Mandatory minute volume (MMV) is one such mode we have explored at Stanford in postoperative cardiac surgery patients. It measures the patient’s expired ventilation and then provides whatever additional ventilation is required to make up a target minute ventilation level. In our hands, use of MMV only slightly influenced our very short postoperative ventilatory period, but it diminished the need to change ventilator parameters (from a mean of six changes to one) and simplified weaning. Proportional and pressure assist ventilation modes adjust pressure support in response to patient efforts. These modes are appealing in theory because they are potentially more comfortable and might hasten weaning.

**Indexes Useful in Predicting Successful Extubation**

Conventional weaning indexes have been based on FVC, MIP, and fractional inspired oxygen requirement (FIO2). The indexes can be divided into oxygenation criteria and ventilatory criteria and are outlined in Table 3.

Although these parameters are useful in otherwise healthy patients, as well as patients who have been intubated for a short-term period (< 1 week), they are insensitive for patients with CO2 retention, un-
derlying pulmonary disease, or patients who have been receiving long-term ventilation.32 Also, none of these criteria assess the patient’s ability to protect his or her airway.33

Another consideration during mechanical ventilation is that additional work is imposed by the resistance of endotracheal tubes, breathing circuitry and demand, and PEEP valves.34 This may be overcome by pressure support or evaluated and taken into consideration by assaying work of breathing (WOB).34 When WOB was assessed using a special apparatus by Kirton et al,34 16% of patients who would have otherwise failed extubation criteria using standard parameters were successfully extubated. The reintubation rate was 4%. The normal physiologic WOB has been established to be < 0.75 J/L in adults.35 Kirton et al,34 however, defined the total WOB to be equal the physiologic WOB plus the imposed WOB. In their study, if the total WOB was 0.8 J/L, the patient was extubated. If total WOB was > 0.8 J/L, then the imposed WOB was measured and subtracted from total WOB to obtain a value for the physiologic WOB. If this value was < 0.8 J/L, the patient was then extubated.34 Levy et al35 stress that the total WOB alone may not be an accurate indicator of successful extubation, particularly in patients with COPD or obesity, ARDS, or pneumonia. Dehaven et al36 restricted WOB assays to tachypneic

<table>
<thead>
<tr>
<th>Mode</th>
<th>Description</th>
<th>Indication</th>
</tr>
</thead>
<tbody>
<tr>
<td>CMV—controlled mechanical ventilation</td>
<td>Preselected rate; does not allow spontaneous breathing</td>
<td>Paralyzed or sedated patients</td>
</tr>
<tr>
<td>CPPV—continuous positive pressure ventilation</td>
<td>Positive pressure ventilation with a preset end-expiratory pressure; does not allow spontaneous breathing</td>
<td>Apnea, neuromuscular disease, requires sedation or paralysis</td>
</tr>
<tr>
<td>AC—assist control</td>
<td>Patient triggers with controlled backup rate</td>
<td>Facilitates patient control of rate, minute volume</td>
</tr>
<tr>
<td>PC—pressure controlled</td>
<td>Inhalation phase is pressure limited, time cycled with no spontaneous respirations</td>
<td>Achieves adequate oxygenation at lower peak airway pressures</td>
</tr>
<tr>
<td>PC-IRV—with inverse ratio ventilation</td>
<td>Improves FRC due to decreased exhalation time but can cause air-trapping</td>
<td></td>
</tr>
<tr>
<td>IMV</td>
<td>Mechanical breaths provided at a preset interval; sufficient peak gas flow between mandatory breaths to satisfy patient’s peak demand</td>
<td>Allows graded decrements in rate in spontaneously breathing patient</td>
</tr>
<tr>
<td>SIMV—synchronized IMV</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FSV</td>
<td>Offsets resistance of breathing apparatus; can be used with or without IMV</td>
<td></td>
</tr>
<tr>
<td>Pressure assist</td>
<td>Adjusts pressure support in response to patient’s effort</td>
<td>Optimally comfortable mode for many patients</td>
</tr>
<tr>
<td>MMV</td>
<td>Machine adjusts level of pressure support to provide fixed total minute ventilation</td>
<td>Assures minimal minute volume and useful for weaning</td>
</tr>
<tr>
<td>CPAP—continuous positive airway pressure ventilation</td>
<td>Maintains PEEP during spontaneous ventilation</td>
<td>Restores FRC toward normal</td>
</tr>
<tr>
<td>APRV—airway pressure release ventilation</td>
<td>Adjust rate of opening of release valve to control minute ventilation</td>
<td>Sometimes used as ventilatory method to minimize airway pressure</td>
</tr>
<tr>
<td>HFJV—high-frequency jet ventilation</td>
<td>100–150 breaths/min 5–50 psig</td>
<td></td>
</tr>
<tr>
<td>HFPPV—high-frequency positive pressure ventilation</td>
<td>100–300 mL tidal volume passive exhalation</td>
<td></td>
</tr>
</tbody>
</table>

*Adapted from Banner et al.27

<table>
<thead>
<tr>
<th>Oxygenation Criteria</th>
<th>Ventilation Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\text{PaO}_2 &gt; 60 \text{ mm Hg on FiO}_2 &lt; 0.40$</td>
<td>$\text{PaCO}_2 &lt; 50$ and $\text{pH} &gt; 7.35$</td>
</tr>
<tr>
<td>A-a gradient &lt; 300 mm Hg (PEEP &lt; 5 cm H$_2$O when performing these measurements)</td>
<td>Respiratory rate &lt; 30</td>
</tr>
<tr>
<td>Spontaneous tidal volume &gt; 5 mL/kg, FVC &gt; 10 mL/kg, MIP &lt; 20 cm H$_2$O, VE &lt; 10 L/min and &lt; 0.5 $\times$ MVV</td>
<td></td>
</tr>
</tbody>
</table>

*A-a gradient = alveolar-arterial oxygen partial pressure gradient; VE = minute volume; MVV = maximal voluntary ventilation.
patients in an otherwise standard weaning protocol. Using this technique, they found that 18% of patients would have otherwise remained intubated due to tachypnea.36

Pragmatically, the RSBI has become the most widely used method for predicting successful extubation, because of its simplicity. The RSBI is simply the ratio of breathing frequency to tidal volume measured under conditions of spontaneous ventilation. If > 105, it predicts weaning failure.37 This is most helpful in patients with no underlying pulmonary disease who have been ventilated mechanically for < 8 days.33 Jacob et al38 found that measuring the RSBI just before and at 30 min of weaning was highly predictive of weaning outcome in postoperative patients. The RSBI, of course, does not predict postextubation pulmonary edema or stridor, so that it remains necessary to treat hypervolemia prior to extubation.38 Lee et al39 caution that the RSBI is not a good indicator for weaning in medical patients with underlying pulmonary disease.

Another parameter is measurement of the tracheal occlusion pressure (P0.1) defined as the inspiratory pressure generated 0.1 s after airway occlusion. Values < 2 cm H2O are good indicators of adequate central respiratory drive.53

In attempt to integrate a variety of measurements into a simple index that can be calculated (since no single measurement seems to work in all patients), several indexes have been developed. CROP is an acronym for an integrated index of Compliance, Rate, Oxygenation, and maximum inspiratory Pressure.37 It attempts to reflect pulmonary gas exchange, as well as the balance between respiratory demand and reserve. Scores > 13 have been associated with successful weaning. The adverse factor/ventilator score combines multiple adverse factors with six ventilatory support parameters. Indexes > 55 are associated with failure to wean.33 Another yardstick, the weaning index (WI), is a measure of ventilatory endurance, pressure-time product, and an estimate of the efficacy of gas exchange. A value < 4 is associated with successful weaning.33 The WI and P0.1 are probably the most accurate indexes because they best reflect the abnormalities that result in failed extubation (increased WOB and drive to breathe) but they are not widely available. Because of simplicity and ready availability, the RSBI remains the most valuable test (Table 4).

In recent years, it is increasingly apparent that use of some index or protocol, as compared with physician “best judgment,” is clinically useful. In a randomized, controlled comparison of protocol-directed vs physician-directed weaning, protocol-guided weaning was more rapid (median of 35 h vs 44 h).40 In fact, even use of divergent protocols, as long as they are reasonable, seems to be more effective than physician-directed protocols, since in this study, the medical directors of four different ICUs each devised a unique protocol.40

### Table 4—Neuer Criteria for Extubation*

<table>
<thead>
<tr>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. RSBI = frequency/tidal volume.</td>
</tr>
<tr>
<td>2. Tracheal occlusion pressure at 100 ms (P0.1) = inspiratory pressure</td>
</tr>
<tr>
<td>100 ms after onset of inspiration.</td>
</tr>
<tr>
<td>3. Compliance, rate, oxygenation, maximum inspiratory pressure</td>
</tr>
<tr>
<td>(CROP) = (C × PImax × PaO2/PAO2)/f), where C = dynamic compliance in</td>
</tr>
<tr>
<td>dynes, PImax = maximal inspiratory pressure in cm H2O, and f =</td>
</tr>
<tr>
<td>spontaneous respiratory rate in breaths per minute.</td>
</tr>
<tr>
<td>4. WI = [(Pbreath/MIP) × T/Total] × VE/Vt, where Pbreath is average</td>
</tr>
<tr>
<td>inspiratory pressure, T/Total is the proportion of the respiratory</td>
</tr>
<tr>
<td>cycle during inspiration, VE is minute volume when Po2 is 40 mm H2O, and</td>
</tr>
<tr>
<td>Vt is tidal volume.</td>
</tr>
</tbody>
</table>

*See text for further explanation of terms.

### Weaning

In the past, three standard weaning trials have been used: the T-tube method, IMV trials, and pressure support ventilation (PSV). The T-tube method allows for intermittent trials of spontaneous ventilation that are progressively lengthened until the patient can be extubated. IMV weaning permits a gradual decrease of the volume-cycled ventilatory rate. Pressure support weaning, in contrast, incrementally lowers the pressure provided with each spontaneous breath. A prospective randomized trial of these three weaning methods indicated that a once-daily trial of spontaneous ventilation led to extubation three times more rapidly than IMV and twice as rapidly as PSV.41 A similar study examined the use of respiratory therapists screening patients for extubation, followed by a 2-h trial of spontaneous ventilation to identify patients capable of breathing spontaneously. This method shortened the duration of mechanical ventilation by about 25%.42 In aggregate, these studies indicate that physicians are slow to recognize patients capable of extubation and that spontaneous ventilation trials may be useful in uncovering those capable of extubation.

### Failure to Wean

Failure to wean is usually the result of one of two processes—oxygenation failure or ventilatory failure. Oxygenation failure most commonly is associated with alveolar filling processes or low lung volumes. Ventilatory failure implies a mechanical or neuro-
muscular disorder with impaired ventilation and hypercarbia; it most commonly reflects inspiratory muscle fatigue. The most common sequence of events in patients failing to wean is progressive tachypnea, paradoxic abdominal wall motion, and a cyclical change in breathing pattern in which the intercostal, abdominal, and diaphragmatic muscles alternate in assisting breathing. In the extubated patient in whom extubation fails, reintubation should be considered if the vital capacity falls below 10 to 15 nL/kg, PaO₂ < 50 to 55 mm Hg on FIO₂ of 50%, respiratory rate > 35 to 40 breaths/min, and inspiratory flow < 25 L/s. These guidelines vary with the patient’s clinical appearance.

After weaning failure, possible correctable factors must be addressed. Nutrition should be maximized without carbohydrate loading, and metabolic abnormalities should be corrected. Cardiovascular function and volume status should be reassessed. Discontinuing sedation should frequently be a major goal. Neuromuscular dysfunction, if not diagnosed, should be evaluated. Sleep cycles are best optimized to minimize patient fatigue. In patients with severe sleep apnea, progesterone may be of value as a respiratory center stimulant. Bronchodilators are appropriate for obstruction, and theophylline may be useful for its effects on central drive and diaphragm fatigability. If a correctable abnormality is found, selective use of noninvasive ventilation with a ventilatory support system (BiPAP) may prevent reintubation. Pulmonary edema is the condition most approachable this way.

**Conclusions**

A host of factors must be considered in the postoperative evaluation and ventilatory treatment of patients. The care team must evaluate the medical history, presurgical and postsurgical drug use, and physiologic parameters before delineating an appropriate postoperative plan. With currently available modes of ventilation, patient therapy can now be more individualized. Protective ventilatory schemes are being explored that seek to avoid shear stress by maintaining enough PEEP to keep the lung inflated, while providing low enough tidal volumes to avoid overinflations of the lung. Finally, physiologic measurements and current weaning techniques are more sophisticated and allow the physician greater certainty in evaluating each patient’s readiness for extubation.

**References**


**Perioperative Cardiopulmonary Evaluation and Management**