AARC Clinical Practice Guideline

Removal of the Endotracheal Tube—2007 Revision & Update

RET 1.0 PROCEDURE
Elective removal of the endotracheal tube from adult, pediatric, and neonatal patients.

RET 2.0 DESCRIPTION/DEFINITION
The decision to discontinue mechanical ventilation involves weighing the risks of prolonged mechanical ventilation against the possibility of extubation failure.[1,2] This guideline will focus on the predictors that aid the decision to extubate, the procedure referred to as extubation, and the immediate postextubation interventions that may avoid potential reintubation. This review will not address weaning from mechanical ventilation, accidental extubation, nor terminal extubation.

2.1 The risks of prolonged translaryngeal intubation include but are not limited to:
- **2.1.1** Sinusitis[3,4]
- **2.1.2** Vocal cord injury[5]
- **2.1.3** Laryngeal injury[6-8]
- **2.1.4** Laryngeal stenosis[6,7]
- **2.1.5** Subglottic stenosis in neonates[9-11] and children[12]
- **2.1.6** Tracheal injury[13-16]
- **2.1.7** Hemoptysis[17]
- **2.1.8** Aspiration[18,19]
- **2.1.9** Pulmonary infection[20-23]
- **2.1.10** Endotracheal tube occlusion[24-27]
- **2.1.11** Accidental extubation necessitating emergent reintubation[25,28]

2.2 Extubation may result in the following complications
- **2.2.1** Upper airway obstruction from laryngospasm[29-32]
- **2.2.2** Laryngeal edema[33-37]
- **2.2.3** Supraglottic obstruction[38]
- **2.2.4** Pulmonary edema[39-41]
- **2.2.5** Pulmonary aspiration syndrome[19,42]
- **2.2.6** Impaired respiratory gas exchange

RET 3.0 ENVIRONMENT
The endotracheal tube should be removed in an environment in which the patient can be physiologically monitored and in which emergency equipment and appropriately trained health care providers with airway management skills are immediately available (see RET 10.0 and 11.0).

RET 4.0 INDICATIONS/OBJECTIVES
When the airway control afforded by the endotracheal tube is deemed to be no longer necessary for the continued care of the patient, the tube should be removed. Subjective or objective determination of improvement of the underlying condition impairing pulmonary function and/or gas exchange capacity is made prior to extubation.[2] To maximize the likelihood for successful extubation, the patient should be capable of maintaining a patent airway and generating adequate spontaneous ventilation. In general, this requires the patient to possess adequate: central inspiratory drive, respiratory muscle strength, cough strength to clear secretions, laryngeal function, nutritional status, and clearance of sedative and neuromuscular blocking effects.

4.1 Occasionally, acute airway obstruction of the artificial airway due to mucus or mechanical deformation mandates immediate removal of the artificial airway. Reintubation or other appropriate techniques for reestablishing the airway (ie, surgical airway management) must be used to maintain effective gas exchange.[26,27,43]
4.2 Patients in whom an explicit declaration of the futility of further medical care is documented may have the endotracheal tube removed despite failure to meet the above indications.[44,45]

RET 5.0 CONTRAINDICATIONS
There are no absolute contraindications to extubation; however, to maintain acceptable gas exchange

after extubation some patients may require one or more of the following: noninvasive ventilation, continuous positive airway pressure, high inspired oxygen fraction, or reintubation. Airway protective reflexes may be depressed immediately following and for some time after extubation.[18,46] Therefore, measures to prevent aspiration should be considered.

RET 6.0 HAZARDS/COMPLICATIONS

6.1 Hypoxemia after extubation may result from but is not limited to

6.1.1 Failure to deliver adequate inspired oxygen fraction through the natural upper airway[47]

6.1.2 Acute upper airway obstruction secondary to laryngospasm[29-32]

6.1.3 Development of post-obstruction pulmonary edema[39-41]

6.1.4 Bronchospasm[48,49]

6.1.5 Development of atelectasis, or lung collapse[50]

6.1.6 Pulmonary aspiration[18,19,42]

6.1.7 Hypoventilation[51,52]

6.2 Hypercapnia after extubation may be caused by but is not limited to

6.2.1 Upper airway obstruction resulting from edema of the trachea, vocal cords, or larynx[33-38]

6.2.2 Respiratory muscle weakness[53,54]

6.2.3 Excessive work of breathing[55-59]

6.2.4 Bronchospasm[48,49]

6.3 Death may occur when medical futility is the reason for removing the endotracheal tube.

RET 7.0 LIMITATIONS OF METHODOLOGY/ VALIDATION OF RESULTS

Predicting extubation outcome is of significant clinical importance as both extubation delay and unsuccessful extubation are associated with poor patient outcomes.[1,2] However, the literature on this topic is limited by few validated objective measures to accurately predict the extubation outcome for an individual patient.[1,2,60-63] Failed extubation, or the need to reinsert an artificial airway following extubation, is not necessarily an indication of failed medical practice. Patients may need reintubation immediately or after some interval due to inappropriately timed extubation, progression of underlying disease, or development of a new disorder. Therefore, a trial of extubation may be used in some marginal patients with the expectation that the need for reintubation is likely. Extubation failure rates reported in the literature range between 1.8%-18.6% for adults,[1,36,63-65] 2.7%-22% for children,[66-70] and may be as high as 40%-60% for low birth-weight infants.[71-75] Clinical practice standards for endotracheal tube removal include attentive postextubation monitoring, prompt identification of respiratory distress, maintenance of a patent airway and, if clinically indicated, attempts to successfully establish an artificial airway by reintubation or surgical technique. The failure and complication rates of extubation can be used as quality monitors.

RET 8.0 ASSESSMENT OF EXTUBATION READINESS

The endotracheal tube should be removed as soon as the patient no longer requires an artificial airway. Patients should demonstrate some evidence for the reversal of the underlying cause of respiratory failure and should be capable of maintaining adequate spontaneous ventilation and gas exchange. The determination of extubation readiness may be individualized using the following guidelines.

8.1 Patients with an artificial airway to facilitate treatment of respiratory failure should be considered for extubation when they have met established extubation readiness criteria.[64,76] Examples of these criteria include but are not limited to

8.1.1 The capacity to maintain adequate arterial partial pressure of oxygen (P_{aO_2}/F_{IO_2} ratio > 150-200) on inspired oxygen fractions provided with simple oxygen devices ($F_{IO_2} \leq 0.4$ to 0.5 and with low levels of positive airway pressure (PEEP) ≤ 5 to 8 cm H_2O[2]

8.1.2 The capacity to maintain appropriate pH (pH ≥ 7.25)[2] and arterial partial pressure of carbon dioxide during spontaneous ventilation[74,75]

8.1.3 Successful completion of 30-120 minute spontaneous breathing trial (SBT) performed with a low level of CPAP (eg 5 cm H_2O) or low level of pressure support eg 5-7 cm H_2O) demonstrating adequate respiratory pattern and gas exchange, hemodynamic stability, and subjective comfort[77-81]

8.1.4 In adults, respiratory rate < 35 breaths per minute during spontaneous breathing;[54] in infants and children, the acceptable respiratory rate decreases inversely with age and can be measured with good repeatability with a stethoscope[82]

8.1.5 Adequate respiratory muscle strength[83-85]

8.1.6 Maximum negative inspiratory pressure > -30 cm H_2O[86-89] although current clinical practice may accept a maximum negative inspiratory pressure > -20 cm H_2O[90,91]

8.1.7 Vital capacity > 10 mL/kg ideal body weight[92] or in neonates > 150 mL/m^2 [89]

8.1.8 Pressure measured across the diaphragm during spontaneous ventilation < 15% of maximum[93,94]

8.1.9 In adults, spontaneous exhaled minute ventilation < 10 L/min[86]

8.1.10 In adults, a rapid shallow breathing index (RSBI, respiratory rate-to-tidal-volume ratio) of ≤105 breaths/min (positive predictive value (PPV) of 0.78)[90]; in infants and children, variables standardized by age or weight proved more useful. Modified CROP index (compliance, resistance, oxygenation, and ventilating pressure) above a threshold of ≥ 0.1-0.15 mL · mmHg/breaths/min/kg) (sensitivity of 83% and specificity of 53%) may be a superior screening tool than a modified RSBI ≤ 8-11 breaths/min/mL/kg (sensitivity of 74% and specificity of 74%)[67,68,95]

8.1.11 Thoracic compliance > 25 mL/cm H_2O[96]

8.1.12 Work of breathing < 0.8 J/L[97-102]

8.1.13 Oxygen cost of breathing < 15% total especially for those patients with chronic respiratory insufficiency requiring long-term mechanical ventilation (sensitivity, 100%; specificity, 87%)[102-104]

8.1.14 Dead-space-to-tidal-volume ratio (V_D/V_T) < 0.6; in children, $V_D/V_T \leq 0.5$ equates to 96% successful extubation, 0.51-0.64 equates to 60% successful extubation, (0.65 equates to 20% successful extubation[105,106]

8.1.15 Airway occlusion pressure at 0.1 seconds ($P_{0.1}$) < 6 cm H_2O and when normalized for maximal inspiratory pressure (MIP), as indicated by [$P_{0.1}$/MIP], accurately predict successful extubation 88% and 98% of the time, respectively.[107-109] (This measurement is primarily a research tool.)

8.1.16 Maximum voluntary ventilation > twice resting minute ventilation[86]

8.1.17 In preterm infants, minute ventilation testing vs. standard clinical evaluation resulted in shorter time to extubation[110]

8.1.19 Peak expiratory flow (PEF) ≥ 60 L/min after 3 cough attempts measured with an in-line spirometer[111,112]

8.1.20 Time to recovery of minute ventilation to pre-spontaneous breathing trial baseline levels[113]

8.1.21 Sustained maximal inspiratory pressures (SMIP) > 57.5 pressure time units (sensitivity and specificity of 1.0) predicted extubation outcome[114]

8.1.22 In neonates, total respiratory compliance (C_{rs}, derived from V_T/PIP-PEEP) ≤ 0.9 mL/cm H_2O was associated with extubation failure, whereas a value ≥ 1.3 mL/cm H_2O was associated with extubation success[115]

8.1.23 Preterm infants extubated directly from low rate ventilation without a trial of endotracheal tube continuous positive airway pressure (CPAP) demonstrated a trend to increased chance of successful extubation (RR = 0.45, CI_{95} (0.19, 1.07), NNT 10[116]

8.1.24 Integrated indices of measured vital capacity (VC, threshold value = 635 mL), respiratory frequency to tidal volume ratio (f/V_T, threshold value = 88 breaths/min/L) and maximal expiratory pressure (MEP, threshold value = 28 cm H_2O)[80,117]

8.2 In addition to treatment of respiratory failure, artificial airways are sometimes placed for airway protection. Resolution of the need for airway protection may be assessed by but is not limited to

8.2.1 Appropriate level of consciousness[118-120]

8.2.2 Adequate airway protective reflexes[119,120]

8.2.2.1 Reduced cough strength (grade 0 to 2) measured by the white card test and increased secretion burden predicted unsuccessful extubation (risk ratio, RR= 4.0; 95% confidence interval (CI_{95}) 1.8 to 8.9)[121]

8.2.3 Easily managed secretions[1,63,119,120]

8.3 In addition to resolution of the processes requiring the insertion of an artificial airway, issues that should be considered in all patients prior to extubation are

8.3.1 No immediate need for reintubation anticipated

8.3.2 Known risk factors for extubation failure

8.3.2.1 Patient features of high risk for extubation failure include: admission to medical ICU, age > 70 or < 24 months, higher severity of illness upon weaning, Hgb <10 mg/dL, use of continuous I.V. sedation, longer duration of mechanical ventilation, presence of a syndromic or chronic medical condition, known medical or surgical airway condition[63,70], frequent pulmonary toilet,[121] and loss of airway protective reflexes[119,120]

8.3.2.2 Risk factors for a known history of a difficult airway: syndromic or congenital conditions associated with cervical instability (ie, Klippel-Feil or Trisomy 21); limited physical access to the airway (ie, halo-vest or anatomic hindrances); multiple failed direct laryngoscopy attempts by an experienced laryngoscopist, or a failed laryngoscopy attempt followed by tracheal intubation using fiberoptic bronchoscopy or nasal lightwand, or requiring placement of a laryngeal mask airway[122-129]

8.3.2.3 In the pediatric cardiothoracic surgery population, presence of one or more of these variables increases the likelihood of failed extubation: age < 6 months, history of prematurity, congestive heart failure, and pulmonary hypertension[130]

8.3.2.4 For pediatric patients, validated bedside measures of respiratory function identifying low (< 10%) and high risk (> 25%) threshold values of extubation failure which may be useful in generating discussion, but do not apply to individual risk[131]

8.3.3 Presence of upper airway obstruction or laryngeal edema as detected by diminished gas leak around the endotracheal tube with positive pressure breaths[37,132-139]

8.3.3.1 Percent cuff leak or the difference between expiratory tidal volume measured with the cuff inflated and then deflated in a volume-controlled mode of ≥15.5% (sensitivity 75%, specificity 72%).[132-138] Yet this test was found not to be predictive in a study of cardiothoracic surgery patients.[139]

8.3.3.2 Air leak may be an age-dependent predictor of postextubation stridor in children. An air leak > 20 cm H_2O was predictive of postextubation stridor in children ≥ 7 years of age (sensitivity of 83%, specificity of 80%), but was not predictive < 7 years of age[37]

8.3.3.3 Air leak test has been predictive of postextubation stridor or extubation failure for children with upper airway pathology: trauma patients,[140] croup,[141] after tracheal surgery.[142]

8.3.4 Evidence of stable, adequate hemodynamic function[2,143-146]

8.3.5 Evidence of stable nonrespiratory functions[147-150]

8.3.6 Electrolyte values within normal range[151-153]

8.3.7 Evidence of malnutrition decreasing respiratory muscle function and ventilatory drive[154-158]

8.3.8 Anesthesia literature indicates the patient must have no intake of food or liquid by mouth for a period of time prior to airway manipulation. The continuation of transpyloric feedings during an extubation procedure remains controversial[159,160]

8.3.9 Prophylactic medication prior to extubation to avoid or reduce the severity of postextubation complications such as

8.3.9.1 Consider use of lidocaine to prevent cough and/or laryngospasm in patients at risk[161,162]

8.3.9.2 Prophylactic administration of steroids may be helpful to prevent reintubation rates in high-risk neonates, but not in children (relative risk, RR = 0.49, CI_{95} 0.01, 19.65) or adults (RR = 0.95, CI_{95} 0.52, 1.72)[61,163]

8.3.9.3 Prophylactic administration of steroids may help reduce the incidence of postextubation stridor in children (RR = 0.53, CI_{95} 0.28, 0.97), but not in neonates or adults (RR = 0.86, CI_{95} 0.57, 1.30)[61,163]

8.3.9.4 Prophylactic administration of steroids for patients with laryngotracheobronchitis (croup) correlates with reduced rates of reintubation[164,165]

8.3.9.5 Caffeine citrate reduced the risk of apnea for infants, but did not reduce the risk of extubation failure[166]

8.3.9.6 Methylxanthine treatment stimulates breathing and reduces the rate of apnea (RR = 0.47, CI_{95} (0.32, 0.70). [Number needed to treat (NNT) 3.7, CI_{95} (2.7, 6.7)] for neonates with poor respiratory drive, especially extremely low birthweight infants.[167]

RET 9.0 ASSESSMENT OF OUTCOME

Removal of the endotracheal tube should be followed by adequate spontaneous ventilation through the natural airway, adequate oxygenation, and no need for re-intubation.

9.1 Clinical outcome may be assessed by physical examination, auscultation, invasive and noninvasive measurements of gas exchange, and chest radiography.

9.2 Quality of the procedure can be systematically assessed by monitoring extubation complications and the need for reintubation.

9.3 The success of removal of the endotracheal tube can be monitored by examining the frequency of reintubation and frequency of complications.

9.4 When a patient experiences an unplanned self-extubation and does not require reintubation, this suggests that planned extubation should have been considered earlier.[168-173]

9.5 Some patients may require postextubation support or intervention to maintain adequate gas exchange independent of controlled mechanical ventilation.

9.5.1 Noninvasive Respiratory Support

9.5.1.1 Infants extubated to nasal intermittent positive pressure ventilation (NIPPV) were less likely to fail extubation than those infants extubated to nasal continuous positive airway pressure ventilation (NCPAP)[RR = 0.21, CI_{95} (0.10, 0.45); NNT 3, CI_{95} (2, 5)][52]

9.5.1.2 In neonates and premature infants, binasal prong CPAP is more effective at preventing re-intubation than single nasal or nasopharyngeal prongs [RR = 0.59, CI_{95} (0.41, 0.85); NNT 5, CI_{95} (3, 14)][174]

9.5.1.3 In adults, routine use of postextubation noninvasive positive pressure ventilation such as BIPAP is not supported[175-177]

9.5.1.4 In patients with chronic obstructive pulmonary disease (COPD), continuous positive airway pressure (CPAP) of 5 cm H_2O and pressure support ventilation (PSV) of 15 cm H_2O have improved pulmonary gas exchange, decreased intrapulmonary shunt fraction, and reduced patient work of breathing[178]

9.5.2 Postextubation Medical Therapy

9.5.2.1 Aerosolized levo-epinephrine is as effective as aerosolized racemic epinephrine in the treatment of postextubation laryngeal edema in children[35]

9.5.2.2 No randomized studies in neonates have been performed to evaluate the role of nebulized racemic epinephrine for postextubation stridor[179]

9.5.2.3 Heliox may alleviate the symptoms of partial airway obstruction and resultant stridor, improve patient comfort, decrease work of breathing, and prevent reintubation[57,58,140]

9.5.3 Diagnostic Therapy

9.5.3.1 For patients with postextubation complications such as stridor or obstruction, fiberoptic bronchoscopy may provide direct airway inspection and therapeutic interventions (secretion clearance, instillation of drugs, removal of aspirated foreign objects).[180,181]

RET 10.0 RESOURCES

Preparation for extubation includes assuring emergency reintubation equipment and personnel are readily available. The following equipment/supplies must be maintained in close proximity to the patient, in sufficient quantities, and in working condition.

10.1 Equipment

10.1.1 Oxygen source

10.1.2 Devices to deliver oxygen-enriched gas mixtures

10.1.3 High-volume suction source and catheters

10.1.4 Pharyngeal and tracheal suction catheters

10.1.5 Self-inflating or nonself-inflating manual ventilation system

10.1.6 Appropriately sized face masks

10.1.7 Oral and nasopharyngeal airways

10.1.8 Endotracheal tubes of various sizes, cuffed and uncuffed

10.1.9 Translaryngeal intubation equipment (laryngoscope blades, handles, extra batteries, stylettes, surgical lubricant, syringes to inflate cuff)

10.1.10 Airway exchange catheter of various sizes

10.1.11 Laryngeal mask airway (LMA) of various sizes

10.1.12 Equipment for establishing an emergency surgical airway (scalpel, lidocaine with epinephrine, appropriately sized endotracheal or tracheostomy tubes)

10.1.13 Nasogastric tubes of various sizes

10.1.14 Pulse oximeter

10.1.15 Two-channel cardiac monitor

10.1.16 Supplies for arterial puncture and blood gas analysis

10.1.17 Medication for sedation, analgesia, neuromuscular blockade and prevention of raised intracranial pressure as indicated by the individual situation

10.1.18 Carbon dioxide detection devices (qualitative and/or quantitative devices)

10.2 Personnel

10.2.1 Credentialed and/or licensed health care personnel with documented knowledge and demonstrated skills specific to patient assessment and airway management should determine the appropriateness of extubation, be available to assess success, and begin appropriate interventions should immediate complications occur. Personnel skilled in endotracheal intubation and the insertion of invasive airways should be immediately available whenever extubation is performed.

10.2.2 Credentialed and/or licensed health-care personnel with documented knowledge and demonstrated skill in providing oxygen administration devices and suctioning the airway may provide support during the extubation procedure.

10.2.3 In the event of acute obstruction of the artificial airway, anyone with airway maintenance skills may remove the endotracheal tube to save the patient's life[160]

RET 11. 0 MONITORING

Monitoring in the postextubation period includes ensuring the equipment, personnel, and medications are readily available in the event of emergent, postextubation phenomena.[160]

11.1 Appropriately trained personnel need to be readily available to detect cardiopulmonary impairment

11.2 Frequent respiratory evaluation should include: vital signs, assessment of neurologic status, patency of airway, auscultatory findings, work of breathing, and hemodynamic status

11.3 Equipment

11.2.1 Pulse oximeter

11.2.2 Two-channel cardiac monitor

11.2.3 Spygmomanometer and stethoscope

11.2.4 Capnograph

RET 12.0 FREQUENCY

No consensus exists on the appropriate timing of or requirement for tracheostomy placement in the mechanically ventilated patient. Any recommendation will have to consider patient population, etiology of respiratory insult, expected or known duration of mechanical ventilation, balance of risks and perceived benefits of continued mechanical ventilation via tracheostomy as opposed to a translaryngeally-placed endotracheal tube. Past recommendations have been based upon expert consensus.[2,182,183]

12.1 Limited data exist on the rate of successful extubation after a previous failed extubation.

12.1.1 Many clinical studies include the first extubation attempt only

12.1.2 In a pediatric descriptive study, 174/2794 subjects failed extubation [extubation failure rate 6.2%, CI_{95} 5.3,7.1] after the first attempt; 27% (65/174) failed a second extubation attempt; of those patients, 22 extubated successfully after the third extubation attempt.[70]

RET 13.0 STANDARD PRECAUTIONS

Caregivers should exercise Standard Precautions for all patients, follow the Centers for Disease Control and Prevention (CDC) recommendations for control of exposure to tuberculosis and droplet nuclei, and institute appropriate precautions empirically for airborne, droplet, and contact agents pending confirmation of diagnosis in patients suspected of having serious infections.[184-189]

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