New Product Dossier

January, 2011
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</table>
Endotracheal intubation is **only the first step** in airway control.

---

**Scenario A**
The ventilator alarms with high peak inspiratory pressures and your patient desaturates. You feel resistance when you try to advance the suction catheter down the endotracheal tube (ETT), which you suspect is obstructed with respiratory secretions. You can:
- Emergently extubate the patient
- Emergently intubate the patient
- Rescue the ETT by removing the obstructing plug

**Scenario B**
An endotracheally intubated patient is failing to wean from mechanical ventilatory support and appears to have increased work of breathing. You suspect the ETT lumen may be narrowed by accumulated secretions. You can:
- Increase the level of ventilator support
- Perform a tracheostomy
- Clear the ETT secretions with a Rescue Cath™

**Scenario C**
A ventilator-dependent intubated patient has copious secretions that you can hear ‘‘cracking’’ in his ETT, but repeated suctioning fails to remove them. You can:
- Aggressively ‘‘lavage’’ the ETT with saline irrigant
- Attempt to suction them out via bronchoscopy
- Rescue the ETT secretions with a Rescue Cath™

**Scenario D**
Bronchoscopy on an intubated patient with pneumonia reveals that the ETT lumen is coated with a thick layer of secretions and biofilm. You are concerned that this may predispose the need for ventilatory support. In addition to systemic antibiotic therapy, you can:
- Attempt bronchoscopic clearance of the ETT
- Perform a tracheostomy
- Clear the ETT with a Rescue Cath™
**CAM Rescue Cath™ Package Labeling**

**Individual Package**

Manufactured by: Omneotech®
Tavernier, FL (USA)
(800) 493-0911
www.omneotech.com

Catheter for suctioning and removing secretions from the endotracheal tube lumen

**Not for use with tracheostomy tube**

<table>
<thead>
<tr>
<th>Product Reference</th>
<th>CAM-RE6095</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contents</td>
<td>1 adult CAM Rescue Cath™</td>
</tr>
<tr>
<td>Endotracheal tube application</td>
<td>6.0 - 9.5 mm. ID</td>
</tr>
<tr>
<td>Catheter Length</td>
<td>38 cm.</td>
</tr>
<tr>
<td>Catheter Diameter (shaft)</td>
<td>8 Fr.</td>
</tr>
<tr>
<td>Catheter Diameter (tip)</td>
<td>12 Fr.</td>
</tr>
</tbody>
</table>

**WARNING: Read Instructions completely before using**

- Read Instructions
- Do not use if package is damaged or open
- Latex Free
- Single Use Only

U.S. Patents: 5709691, 6082361, 6318368, 8494208, 6679262, 7060135. Other U.S. and foreign patents pending. Copyright Omneotech®, Tavernier, FL 33070. All rights reserved.

**Box of 5 catheters**

Manufactured by: Omneotech®
Tavernier, FL (USA)
(800) 493-0911
www.omneotech.com

Catheters for suctioning and removing secretions from the endotracheal tube lumen

**Not for use with tracheostomy tubes**

<table>
<thead>
<tr>
<th>Product Reference</th>
<th>CAM-RE6095</th>
</tr>
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<tbody>
<tr>
<td>Contents</td>
<td>5 adult CAM Rescue Caths™</td>
</tr>
<tr>
<td>Endotracheal tube application</td>
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CAM Rescue Cath™ Instructions for Use

Section 1: General Setup
1. Connect the suction port to a vacuum source via an air sampling bag (Fig. 1). Adjust the vacuum source regulator per institutional guidelines for airway suctioning. Disconnect the suction tubing from the air sampling bag until ready to perform endotracheal tube suctioning.
2. Gently insert the depth calibrator tube and slide it along the slot on the handle, noting that it locks in position when released.
3. Remove the syringe from the balloon inflation port until the depth calibrator tube is filled with 3 ml of air and reattach it to the handle (Fig. 2b). Gradually inflate the balloon, ensuring that the cleaning assembly expands as the balloon fills with air and then deflates when the plunger is released. Empty and replace the syringe for the next step (Fig. 1).

Section 2: Calibration Procedure
1. Hold the CAM Rescue Cath™ next to the patient’s endotracheal tube. Align the marked calibrations on the CAM Rescue Cath™ with the corresponding numbers on the endotracheal tube (Fig. 2).
2. Depress and advance the depth calibrator tube until the depth calibrator disk abuts the top of the endotracheal tube (Fig. 3).
3. Make note of the "calibrated position," which marks the proper calibration depth for the CAM Rescue Cath™ to be used for the following indicated depth calibrator disks (Fig. 4).
4. If the vacuum tubing was disconnected from the endotracheal tube calibration procedure, reconnect it to the endotracheal tube.
5. Take care not to move the depth calibrator tube or depth calibrator disk from the calibrated position during suctioning or cleaning of the endotracheal tube.

Section 3: Endotracheal Tube Cleaning Procedure
1. Calibrate the CAM Rescue Cath™ to the patient’s endotracheal tube as follows:
   a. Hold the CAM Rescue Cath™ to the patient’s endotracheal tube as shown (Fig. 5).
   b. Insert the suction port and air sampling bag into the patient’s endotracheal tube as shown (Fig. 6).
   c. Insert the suction port into the patient’s endotracheal tube until the depth calibrator disk abuts the endotracheal tube (Fig. 7).
   d. Depress the depth calibrator tube until the depth calibrator disk abuts the endotracheal tube (Fig. 8).
   e. Gently insert the cleaning assembly into the patient’s endotracheal tube (Fig. 9).
   f. Suction the airway for 15 seconds (Fig. 10).
   g. Remove the cleaning assembly from the endotracheal tube and inspect the endotracheal tube for cleanliness (Fig. 11).

Section 4: Endotracheal Tube Suctioning Procedure
1. Calibrate the CAM Rescue Cath™ to the patient’s endotracheal tube as follows:
   a. Ensure that the CAM Rescue Cath™ balloon remains inflated during airway suctioning. Connect the suction tubing to the suction port and apply suction at the desired level (Fig. 12).
   b. Depress the depth calibrator tube until the depth calibrator disk abuts the endotracheal tube (Fig. 13).
   c. Gently insert the cleaning assembly into the endotracheal tube and advance the catheter into the endotracheal tube at the desired suction level (Fig. 14).
   d. Suction the airway for 15 seconds (Fig. 15).
   e. Remove the cleaning assembly and inspect the endotracheal tube for cleanliness (Fig. 16).
   f. Reconnect the suction tubing to the suction port and apply suction at the desired level (Fig. 17).

For product inquiries, contact Omneotech at info@omneotech.com or 1-800-493-0911.
To reorder product, contact your local distributor.
**Guidelines for Use of the Omneotech™ CAM Rescue Cath™ in General Practice and in Conjunction with Clinical Protocols for Ventilator Weaning and Airway Procedures**

**Objective:** To increase the patency (thereby reducing airway resistance) of the endotracheal tube (ETT) by mechanically removing viscous respiratory secretions (mucus, blood, biofilm) adherent to the ETT lumen.

**Rationale:** Decreasing airway resistance and imposed work of breathing (WOB\text{\textsubscript{imp}}) by removing obstructing secretions should improve the success of ventilator weaning and extubation in patients in whom reduced ETT patency is the cause of weaning failure.

**CAM Rescue Cath™ use as a Therapeutic Tool – Target Patient Population**

Use of the CAM Rescue Cath™ in specific clinical scenarios may help prevent the need for emergent extubation or ETT exchange and/or facilitate the weaning of specific subsets of ‘failure-to-wean’ patients.

1. Sudden ETT occlusion manifested by: tachypnea, hypoxia, hypertension or hypotension, bradycardia, restlessness, diaphoresis, chest retractions, use of accessory breathing muscles, cyanosis.
2. Need to replace a vent circuit component due to mechanical malfunction or soiling from secretions.
3. Resistance to passage of a suction catheter through the ETT.
4. Frequent or recurrent ventilator alarms related to high peak pressures.
5. Lower \(O_2\) saturations not attributed to worsening respiratory disease or CXR.
6. Decrease in tidal volume ventilator readings.
7. Need for \(FiO_2\) or pressure support increase over a given time.
8. Duration of intubation exceeds that anticipated by severity of illness.
9. History of suctioning for previous or current blood or blood clots.
10. Respiratory secretions classified as moderately thick to thick.
11. Patient ventilated in the prone position.
13. Characteristic ‘square’ pressure/volume tracing on ventilator graphics display.
14. Measured elevation in pressure drop across the ETT or elevation in WOB\text{\textsubscript{imp}}.
15. Bronchoscopic (direct visual) confirmation of ETT lumen narrowing by secretions.
16. Patient classified as ‘failure-to-wean’ from mechanical ventilation.

**RECOMMEND keep CAM Rescue Cath™ ‘within arm’s reach’ at bedside of patients with an ETT, in code carts and difficult airway carts to ensure immediate availability in life-threatening cases.**

**CAM Rescue Cath™ use as Diagnostic Tool**

Ventilator weaning trial or pre-extubation assessment. Use of the CAM Rescue Cath™ may:

1. **Rule out** ETT occlusion due to secretions in ‘failure-to-wean’ cases. If significant secretions are not retrieved, ‘failure-to-wean’ is probably not related to elevated WOB\text{\textsubscript{imp}} due to ETT occlusion.
2. **Rule in (and resolve)** ETT occlusion by luminal secretions as cause of ‘failure-to-wean’ if secretions are retrieved and significant decrease WOB\text{\textsubscript{imp}} is noted (identified by resolving signs of respiratory distress and improving \(O_2\) sat, RR, HR, BP, Peak Pressures, Tidal Volumes).

**CAM Rescue Cath™ use as Procedure Facilitation Tool**

Bronchoscopy or Percutaneous Tracheostomy. Use of the CAM Rescue Cath™ prior to these may:

1. Facilitate ease and reduce the risk of passing the bronchoscope through the ETT by removing mucus that can be pushed into the bronchi, potentially inoculating them with a microbial bolus.
2. Facilitate a quicker procedure by improving visualization through and beyond ETT.

**ETT exchange for ETT cuff leak.** Use of the CAM Rescue Cath™ prior to this may:

1. Facilitate ease and reduce the risk of passing the ETT exchange catheter through the ETT by removing mucus that can be pushed into the bronchi, inoculating them with a microbial bolus.
2. Help ensure the ETT exchange catheter lumen and the ETT lumen area between the ETT and ETT exchange catheter will remain as patent as possible during procedure.

**References**


Lewis RM. Airway clearance techniques for the patient with an artificial airway. Respir Care. 2002 Jul; 47(7):808-17


Omneotech™ 3/2010

www.omneotech.com
CAM Rescue Cath™ Safety Considerations

Safety by Design

- Package labeling
  - No latex
  - Sterilized
  - Detailed Instructions for Use

- Cleaning assembly defaults to the collapsed state, averting inadvertent airway obstruction
  - Balloon-based cleaning assembly, so default setting = deflation
  - No air lock on syringe, so default setting = deflation
  - Mesh has memory and the collapsed orientation promotes balloon deflation

- Limited insertion into ETT
  - Distance markers and depth calibrator facilitate calibration of the CAM Rescue Cath™ to the length of the patient’s ETT
  - Depth calibrator has a locking feature to help hold it in position during use

- In case of inadvertent over-insertion through ETT
  - Cleaning assembly will expand to a maximum of 1 cm. diameter (limited by balloon construct and mesh dimensions)
  - Largest syringe that will fit in handle slot is 3 ml. syringe, which limits air instillation into balloon

- Depth calibrator regulated from handle, avoiding contamination risk of catheter components introduced into the ETT

- Patent 2nd lumen facilitates pressure equilibration

- Mushroom tip glides through secretions (rather than pushing them ahead)

- No complications reported from clinical use

Safety by Comparison

- Suctioning deoxygenates patients (Leiman ref.)

- Saline irrigation inoculates patient with contaminated secretions (Hagler ref.)

- Bronchoscopy is lengthy, deoxygenates and inoculates patients (Mort ref.)

- Reintubation or ETT Exchange can result in cascading sets of serious complications
**SECRETION-RELATED ENDOTRACHEAL TUBE OBSTRUCTIONS: CLINICAL FACTORS AND EFFICACY OF OBSTRUCTION REMOVAL USING NEW COMPLETE AIRWAY MANAGEMENT (CAM) CATHETERS™**

ETT patency following each step in experimental protocol

<table>
<thead>
<tr>
<th>Protocol step</th>
<th>Patency (%)</th>
<th>p value for difference from SXN</th>
<th>Patency (%)</th>
<th>p value for difference from SXN</th>
<th>Patency (%)</th>
<th>p value for difference from SXN</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ave.</td>
<td>Range</td>
<td>Ave.</td>
<td>Range</td>
<td>Ave.</td>
<td>Range</td>
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<tr>
<td>1) Extubation</td>
<td>87</td>
<td>46-97</td>
<td>n/a</td>
<td>72</td>
<td>4-90</td>
<td>n/a</td>
</tr>
<tr>
<td>2) SXN with patients’ 14 Fr. catheter</td>
<td>90</td>
<td>61-98</td>
<td>n/a</td>
<td>78</td>
<td>48-98</td>
<td>n/a</td>
</tr>
<tr>
<td>3) MC with CAM Rescue Cath™</td>
<td>96</td>
<td>91-100</td>
<td>0.009</td>
<td>93</td>
<td>82-100</td>
<td>0.0008</td>
</tr>
<tr>
<td>4) MC with CAM Endotrach Cath™</td>
<td>97</td>
<td>92-100</td>
<td>0.0041</td>
<td>94</td>
<td>83-100</td>
<td>0.0004</td>
</tr>
</tbody>
</table>

This determines WOB_imp

Three sets of bars denote secretions of thin, moderately thick and thick consistency following MV for 1 to 27 days. Patency at narrowest point in the ET tube was calculated from acoustic reflectometry (red bars = pre-interventions). The **CAM Rescue Cath™** (blue bars) consistently removed ET tube secretions more effectively than 14 Fr. suction catheters (yellow bars) in all secretion categories, resulting in significantly improved ET tube patency.
SECRETION-RELATED ENDOTRACHEAL TUBE OBSTRUCTIONS: CLINICAL FACTORS AND EFFICACY OF OBSTRUCTION REMOVAL USING NEW COMPLETE AIRWAY MANAGEMENT (CAM) CATHETERS™

**ETT patency (%) stratified by clinical impression of secretion quantity**

- Post Extubation
- 14 Fr suction catheter
- CAM Rescue Cath
- CAM Endotrach Cath

<table>
<thead>
<tr>
<th>Clinical impression of secretion quantity</th>
<th>None</th>
<th>Small</th>
<th>Moderate</th>
<th>Large</th>
</tr>
</thead>
<tbody>
<tr>
<td>Post Extubation</td>
<td>0.94%</td>
<td>2.3%</td>
<td>77.9%</td>
<td>82.7%</td>
</tr>
<tr>
<td>14 Fr suction catheter</td>
<td>0.94%</td>
<td>2.3%</td>
<td>82.7%</td>
<td>77.9%</td>
</tr>
<tr>
<td>CAM Rescue Cath</td>
<td>0.94%</td>
<td>2.3%</td>
<td>78.3%</td>
<td>74.8%</td>
</tr>
<tr>
<td>CAM Endotrach Cath</td>
<td>0.84%</td>
<td>2.3%</td>
<td>74.8%</td>
<td>77.9%</td>
</tr>
</tbody>
</table>

**ETT patency (%) stratified by circuit humidification technique**

- post extubation
- 14 Fr suction catheter
- CAM Rescue Cath
- CAM Endotrach Cath

<table>
<thead>
<tr>
<th>Circuit humidification</th>
<th>HME</th>
<th>HW</th>
</tr>
</thead>
<tbody>
<tr>
<td>post extubation</td>
<td>69.3%</td>
<td>93.3%</td>
</tr>
<tr>
<td>14 Fr suction catheter</td>
<td>77.1%</td>
<td>94.7%</td>
</tr>
<tr>
<td>CAM Rescue Cath</td>
<td>94.7%</td>
<td>99.3%</td>
</tr>
<tr>
<td>CAM Endotrach Cath</td>
<td>94.7%</td>
<td>99.3%</td>
</tr>
</tbody>
</table>
Mechanism of action of the CAM Rescue Cath™: Ventilator Waveforms

BEFORE

AFTER

“I have noticed that you can sometimes predict the need for the Rescue Cath by the waveform. See attached. Pre wave form: note the irregularities in the Press Wave and the delay exp flow wave that does not return to baseline. Immediately after one pass [with the Rescue Cath] there is now a normal Press and Flow waveform…”

George W. Kopp RRT
Surgical Team Coordinator
Dept of Respiratory Care
Hartford Hospital

(Corresponding pictures of CAM Rescue Cath™ with retrieved ETT mucus.)

Comments and all images used with permission from George Kopp RRT, Hartford Hospital, CT.
**Mechanism of action of the CAM Rescue Cath™: Bronchoscopy**

**BEFORE**

![Before Image 1]

**AFTER**

![After Image 1]

“ET with thick secretions throughout cleared with Rescue Cath.”

**BEFORE**

![Before Image 2]

**AFTER**

![After Image 2]

**Figure 1.** Bronchoscopic view of ETT lumen. This was present at various levels in the distal two-thirds of the ETT.

**Figure 3.** Luminal patency: single-pass improvement with CAM Rescue Cath.
Mechanism of action of the CAM Rescue Cath™: Fluoroscopy

Step 1: catheter is introduced into ET tube
- Rescue Cath™ tip
- secretions

Step 2: balloon inflation
- balloon
- Rescue Cath™ tip
- secretions

As balloon fills, catheter lumen prevents complete ET tube obstruction

Step 3: catheter withdrawal
- balloon
- Rescue Cath™ tip
- secretions

Secretions are trapped proximal to the balloon

ETT patency was re-established with the CAM Rescue Cath™ without:
- suctioning
- saline instillation
- bronchoscopy
- re-intubation
Mechanism of action of the CAM Rescue Cath™: Acoustic Reflectometry

Examples of Acoustic Reflectometry Waveforms

ET tube Patency

14 Fr suction catheter

baseline

Rescue Cath™

14 Fr suction catheter

baseline

Rescue Cath™
In the non-intubated patient, how important is the establishment and maintenance of a patent airway?

When the endotracheal tube becomes the defacto airway, how important is it to maintain its patency?
The medical literature reports a variety of serious problems related specifically to the artificial airway of mechanically ventilated patients. They are outlined below, with source citations following each reference. The CAM Rescue Cath™ may positively impact each of these through improved removal of endotracheal tube lumen secretions.

1. **Remove ET tube obstructions that can increase flow resistance and may lead to difficulties in weaning from mechanical ventilation.**

   Poiseuille’s Equation

   $$ R \propto \frac{\eta \cdot L}{r^4} $$

   “Inadvertent endotracheal tube obstruction was common in patients requiring mechanical ventilation and **may be significant as early as at 24 h.** Moderate obstruction in endotracheal tube lumens should be suspected in cases of difficulties in weaning, even in patients who were ventilated for less than 1 day.”

   Endotracheal tube intraluminal diameter narrowing after mechanical ventilation: use of acoustic reflectometry


2. **Restore ET tube patency without emergent extubation or tube exchange.**

   “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.”

   AARC Clinical Practice Guideline: Removal of the Endotracheal Tube - 2007 Revision & Update


3. **Remove ET tube secretions that may include biofilm, a suspected source of microorganisms known to cause VAP.**

   “Infected biofilm in the endotracheal tube, with subsequent embolization to distal airways, may be important in the pathogenesis of VAP (Level III).”

   Guidelines for the Management of Adults with Hospital-acquired, Ventilator-associated, and Healthcare-associated Pneumonia

The **CAM Rescue Cath™** is an airway management tool with a variety of uses and related benefits:

- **Ventilator Weaning tool**
  - Help facilitate weaning of some ‘weaning intolerant’ patients
  - Reduce ventilator-related complications by reducing vent days
  - Reduction of vent days improves ICU throughput
  - Reduce all related costs

- **ETT Obstruction Clearance tool**
  - Avoid unplanned extubations and all related complications
  - Reduce vent days and VAP risk related to unplanned extubations/reintubations
  - Faster intervention by first responder to obstructed ETT and/or ‘code’ scenarios
  - Reduce all related costs

- **Bronchoscopy adjunct tool**
  - Reduced likelihood of inoculating patient with contaminated ETT secretions
  - Faster procedure because less time spent clearing ETT secretions
  - Less deoxygenation of patient through patent ETT and quicker procedure

- **Percutaneous Tracheostomy adjunct tool**
  - Reduced likelihood of inoculating patient with contaminated ETT secretions
  - Improved visualization through ETT during bronchoscopy
  - Faster procedure because less time spent clearing ETT secretions

- **ETT Exchange (for blown ETT cuff) adjunct tool**
  - Reduced likelihood of inoculating patient with contaminated ETT secretions
Potential Benefits from Rescue Cath™ use for Ventilator Weaning

**The Rescue Loop™**

**A New Ventilator Weaning Paradigm**

Timely weaning and liberation from mechanical ventilation is not just sound clinical practice. It is a patient safety concept.

From zero to infinity

Omneotech

---

**Potential Benefits from Rescue Cath™ use for Ventilator Weaning**

**Isolated “weaning failure” loop**

**New Paradigm**

Proactive ventilator weaning with a Rescue Loop™ protocol

**Work Of Breathing (WOB) during Intubation and Mechanical Ventilation**

- Blue: mechanical ventilation support level
- Pink: WOB (Physiologic + Disease)
- Red: WOB (Imposed) due to ET tube (new)
- Red: WOB (Imposed) due to ET tube narrowing
Potential Savings from Rescue Cath™ use for Sudden ET tube Plugging

**PATIENTS from complications**

<table>
<thead>
<tr>
<th>Blocked Tracheal Tube</th>
<th>ET tube Exchange</th>
</tr>
</thead>
<tbody>
<tr>
<td>62% require CPR and/or vasopressor meds</td>
<td>Hypoxemia 60%</td>
</tr>
<tr>
<td></td>
<td>Bradycardia 8%</td>
</tr>
<tr>
<td></td>
<td>Cardiac arrest 1%</td>
</tr>
<tr>
<td></td>
<td>Surgical Airway 2%</td>
</tr>
<tr>
<td></td>
<td>Esophageal intub. 26%</td>
</tr>
<tr>
<td></td>
<td>Direct laryngoscopy 0-53%</td>
</tr>
</tbody>
</table>

With the Rescue Cath™, the mucus plug comes out...

and the ET tube stays in.

**Extubation**

- Upper airway obstruction from laryngospasm
- Laryngeal edema
- Supraglottic obstruction
- Pulmonary edema
- Pulmonary aspiration syndrome
- Impaired respiratory gas exchange

**Intubation in ICU**

- 26% Severe hypoxia
- 25% Severe hypotension
- 1.6% Cardiac arrest
- 0.8% Death
- 12% Difficult intub.
- 10% Arrhythmia
- 5% Esophageal intub.
- 2% Aspiration
- 1.5% Dental trauma

Wratney AT, Cheifetz IM. Resp Care. Vol 52: No 1, Jan 2007

AARC Clinical Practice Guideline: Removal of the Endotracheal Tube - 2007 Revision & Update

...↑Vent days, ↑ICU days, ↑VAP, ↑hospital days.

**TIME for clinicians**

Reintubation / ET tube Exchange Time Factors

- Respond to bedside
- Prepare for intubation & intubate
- Monitor post intubation, CXR, etc.
- +/- Manage complications
- Documentation

With the Rescue Cath™ in seconds

**MONEY & RESOURCES for hospitals**

Reintubation / ET tube Exchange Cost Factors

- New ET tube +/- stylet
- CO₂ detector
- CXR
- New circuit +/- HME
- Medications
  - Sedation
  - Paralytics
  - Code Rx
- Intub. tray / exchange catheter / surg. tray
- +/- ABG
- +/- sputum cultures, antibiotics, ?VAP
- +/- EKG
- Respiratory Therapist time
- ICU Nurse time
- Physician time
- Prolonged MV after emergent reintubation

With the Rescue Cath™, + one RT

## Financial Benefits of the CAM Rescue Cath™

Judicious use of the CAM Rescue Cath™ may reduce or eliminate costs associated with the following medical events.

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost per single item</th>
<th>Event or Intervention</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Elective reintubation</td>
</tr>
<tr>
<td>Endotracheal tube</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Stylet</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Yankeur</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Ambu bag</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>CO₂ detector</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Intubation meds (sedative, paralytic)</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Syringes for meds / inflate ETT cuff</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Needles to draw up / administer meds</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Ventilator circuit</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>In-line suction catheter</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>HME</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Tube exchange catheter</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Arterial blood gas kit</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Chest radiograph</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Intubation tray</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Difficult intubation cart</td>
<td>+/-</td>
<td>+/-</td>
</tr>
<tr>
<td>Code items</td>
<td></td>
<td></td>
</tr>
<tr>
<td>‘Crash’/‘code’ cart</td>
<td></td>
<td></td>
</tr>
<tr>
<td>EKG</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Defibrillator pads</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Resuscitation meds</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vasopressor drips</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Labs: CBC, BMP, card enz</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sputum culture / specimen trap</td>
<td></td>
<td>+</td>
</tr>
<tr>
<td>Antibiotics</td>
<td></td>
<td>+</td>
</tr>
<tr>
<td>Bronchoscopy cart</td>
<td></td>
<td>+</td>
</tr>
<tr>
<td><strong>Time:</strong> prep, procedure, monitor postproc., f/u labs &amp; xray results, documentation**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Physician</td>
<td>/hr</td>
<td>+</td>
</tr>
<tr>
<td>ICU nurse</td>
<td>/hr</td>
<td>+</td>
</tr>
<tr>
<td>Respiratory therapist</td>
<td>/hr</td>
<td>+</td>
</tr>
<tr>
<td>Radiology technician</td>
<td>/hr</td>
<td>+</td>
</tr>
<tr>
<td>Lab technician</td>
<td>/hr</td>
<td>+</td>
</tr>
<tr>
<td><strong>TOTAL COSTS</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>ADDITIONAL POTENTIAL EXPENSES RELATED TO REINTUBATION</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Additional vent day (in ICU)**</td>
<td>$1,500.00 per day</td>
<td></td>
</tr>
<tr>
<td>VAP (per episode)**</td>
<td>$41,294.00</td>
<td></td>
</tr>
<tr>
<td>Liability for difficult intubation**</td>
<td>$130,000.00</td>
<td>(median lesser injury = $65k, median brain damage /death = $400k)</td>
</tr>
</tbody>
</table>

---

**a** additional costs specific to the institution
**d** hospital charge, may be nonreimbursable by new CMS initiatives for Hospital Aquired Condition
Clinical, financial and legal risk exposure reduction with Rescue Cath™

“How much does it cost?”

In the emergently threatened airway scenario, how much is it worth to prevent a serious adverse event / harm to the patient?

In the less dramatic but far more prevalent failure-to-wean scenario, how much is it worth to reduce vent days for a patient?

Consider what it can save your patients in terms of avoidable complications.

Consider what it can cost you or your institution to NOT use it.

Opportunity to reduce costs and liability for practitioner and institution while helping improve patient outcomes.

Financial Benefits of the CAM Rescue Cath™

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost per unit (in ICU) $</th>
<th>Cost per episode $</th>
<th>Cost of Intubation $</th>
</tr>
</thead>
<tbody>
<tr>
<td>VAP</td>
<td>$1,500.00</td>
<td>$41,294.00</td>
<td>$130,000.00</td>
</tr>
<tr>
<td>Liability for difficult intubation</td>
<td>$65k</td>
<td>$130,000.00</td>
<td></td>
</tr>
</tbody>
</table>

CAM Rescue Cath™ Dossier. Copyright Omneotech® 2011, all rights reserved.
Example #1: Patient with ↑WOB, Failing to Wean from Mechanical Ventilation

“I used the rescue catheter again on a patient. The occlusion was not as obvious as in Mr. [R]’s case. The patient was getting weaning parameters and did well on the NIF, but became tachypneic and showed signs of increased WOB (use of accessory muscles, etc.) and was placed back on the vent overnight. The next morning the RT reported that they had suctioned a moderate-size mucus plug out of the ET tube. The patient's Resp rate was up (high 20's and Vt was decreased) so while the therapist was checking the ET tube, they noticed some tactile fremitus from the tube. We suctioned the patient and had some significant resistance at a specific point. The rescue cath. was used and a large mucus plug was removed. The patient's resp rate decreased to the mid-teen and Vt increased from 400 to 600cc and no signs of resp. distress and was successful extubated and doing well.”

— RRT (MO)

Example #2: Patient with Respiratory Distress from Obstructed ET tube

“The therapist on the other unit ask me to look at as patient that was pressure limiting the vent., and had trouble passing suction cath. Vt volumes had dropped to 120ml, pressure limit @ 60 cmwp. RR @ 32, I was unable to pass suction cath. Used the rescue cath and removed a large mucus plug. Vt increased to 650 ml, airway pressure dropped to 32 cmwp. The lowest SpO2 was 89 % before I used the rescue cath.,

[T]he night therapist had mentioned to me that he has used the rescue several time with simular results.”

— RRT (MO)
3 Clinical Manifestations of ETT Secretions / Biofilm

**Airway Clearance Techniques for the Patient with an Artificial Airway**

Goals of Airway Clearance Techniques (table)...

1. "Prevent catastrophic obstruction of endotracheal tube (relates to location of secretions)

2. Reduce peripheral airway obstruction. Decrease **work of breathing** and improve ventilation/perfusion ratio (relates to quantity of secretions)

3. Reduce infectivity of secretions. Bacterial quantity and antibiotic resistance (relates to quality of secretions)"


**Endotracheal tube intraluminal volume loss among mechanically ventilated patients**

1. "Endotracheal tube occlusion represents a medical emergency among patients requiring mechanical ventilation, necessitating urgent re-establishment of a patent airway (1, 2).

2. Partial occlusion or narrowing of endotracheal tubes, and tracheal narrowing, has been associated with increased patient **work of breathing** and delayed liberation from mechanical ventilation (3– 6).

3. In addition to intraluminal volume loss, the formation of biofilm and the adherence of secretions on the surface of endotracheal tubes has been implicated in the development of **ventilator-associated pneumonia** (7, 8)."

Shah C, Kollef MH

Crit Care Med 2004 Vol. 32, No. 1

---

**Final common pathway of clinical manifestation of ET tube secretions / biofilm**

- **Increase WOB**
- **Increase VAP**

**ETT obstructions**

**Complications**

- Poor patient outcomes
- Increased resource consumption
Once the reintubation or the ET tube exchange is completed, these patients remain at ongoing risk for yet another set of complications in their care, as follows:

**Unplanned Extubation and Reintubation in ICU**
- 11 additional ventilator days
- 11 additional ICU days
- Doubled the risk of VAP
- 16 additional hospital days

---

**Factors associated with blocked tracheal tubes**

<table>
<thead>
<tr>
<th>No. tubes</th>
<th>No. patients</th>
<th>ETT or TT</th>
<th>Blood or Secretions</th>
<th>Total days</th>
<th>Tube days</th>
<th>HMEF duration (hrs)</th>
<th>Tube changed</th>
<th>CPR required</th>
<th>Death at time of episode</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1 (child)</td>
<td>ETT</td>
<td>Secretions</td>
<td>22</td>
<td>10</td>
<td>48</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>1997</td>
</tr>
<tr>
<td>2</td>
<td>1 (child)</td>
<td>TT</td>
<td>Secretions</td>
<td>45</td>
<td>20</td>
<td>48</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>1997</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>ETT</td>
<td>Secretions</td>
<td>1</td>
<td>-</td>
<td>“48”</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>1997</td>
</tr>
<tr>
<td>4</td>
<td>3</td>
<td>TT</td>
<td>Blood</td>
<td>65</td>
<td>7</td>
<td>48</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>1997</td>
</tr>
<tr>
<td>5</td>
<td>4</td>
<td>TT</td>
<td>Blood</td>
<td>48</td>
<td>19</td>
<td>48</td>
<td>Yes (to ETT)</td>
<td>Yes</td>
<td>No</td>
<td>1998</td>
</tr>
<tr>
<td>6</td>
<td>5</td>
<td>ETT</td>
<td>Secretions</td>
<td>3</td>
<td>-</td>
<td>48</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>1998</td>
</tr>
<tr>
<td>7</td>
<td>5</td>
<td>ETT</td>
<td>Secretions</td>
<td>5</td>
<td>-</td>
<td>48</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>1998</td>
</tr>
<tr>
<td>8</td>
<td>6</td>
<td>ETT</td>
<td>Blood</td>
<td>7</td>
<td>-</td>
<td>48</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>1998</td>
</tr>
<tr>
<td>9</td>
<td>7</td>
<td>ETT</td>
<td>Secretions</td>
<td>3</td>
<td>-</td>
<td>48</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>1998</td>
</tr>
<tr>
<td>10</td>
<td>8</td>
<td>ETT</td>
<td>Secretions</td>
<td>6</td>
<td>-</td>
<td>48</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>1998</td>
</tr>
<tr>
<td>11</td>
<td>9</td>
<td>ETT</td>
<td>Both</td>
<td>12</td>
<td>-</td>
<td>48</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>1999</td>
</tr>
<tr>
<td>12</td>
<td>10</td>
<td>TT</td>
<td>Blood</td>
<td>113</td>
<td>35</td>
<td>48</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>1999</td>
</tr>
<tr>
<td>13</td>
<td>11</td>
<td>ETT</td>
<td>Both</td>
<td>2</td>
<td>-</td>
<td>48</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>1999</td>
</tr>
</tbody>
</table>

*Received atropine and adrenaline
Difficult Airway Management—Devices for Every Airway Provider

a report by

Carin A Hagberg, MD and Sarah A Sweeney, BSc

1. Professor and Chair, Department of Anesthesiology, University of Texas Medical School at Houston, and Medical Director, Perioperative Services, and Director, Difficult Airway Management, Memorial Hermann Hospital. 2. Second-year Medical Student, University of Texas Medical School at Houston

Endotracheal Tube Guides
A number of endotracheal (ET) guides have been used to aid in intubation and extubation. Exchanging ET tubes is risky, but is necessary in situations where an acute airway obstruction cannot be cleared or re-intubation is needed to re-establish the airway. Several devices have been designed to make exchange easier for the airway provider and safer for the patient.

Endotracheal exchangers should be handled with caution; the rate of failure seems to be higher than expected depending on the type of AEC, technique and experience of the operator. The user should be aware that ETT exchange can lead to major complications that include laceration of the lateral wall, bronchial perforation with pneumothorax, loss of airway with hypoxemia and/or bradycardia, potential need of a surgical airway, cardiac arrest, or death. A clear algorithm and equipment for alternative ways to control the airway should be ready available before an ETT exchange is performed.
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.\(^{26,27,43}\)

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\(^{48,49}\)
Clinical practice and risk factors for immediate complications of endotracheal intubation in the intensive care unit: A prospective, multiple-center study

- prospective multi-center study
- 253 ET intubations performed in an ICU setting
- "Complications occurred in nearly half of the patients, and serious complications occurred in 28%"

Unplanned Extubation and Reintubation
What is the clinical impact?

Planned extubation (n = 645) vs. Unplanned extubation & reintubation (n = 105)

<table>
<thead>
<tr>
<th></th>
<th>Planned extubation (n = 645)</th>
<th>Unplanned extubation &amp; reintubation (n = 105)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>MV duration</td>
<td>6 days (3-12)</td>
<td>17 days (8-24)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>ICU LOS</td>
<td>9 days (5-17)</td>
<td>22 days (11-40)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Hospital LOS</td>
<td>18 days (9-33)</td>
<td>34 days (22-54)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Chronic care</td>
<td>13.8%</td>
<td>34.3%</td>
<td>0.002</td>
</tr>
</tbody>
</table>

Effect of unplanned Extubation on outcome of mechanical ventilation

Planned extubation (n = 150) vs. Failed unplanned extubation (n = 75)

<table>
<thead>
<tr>
<th></th>
<th>Planned extubation (n = 150)</th>
<th>Failed unplanned extubation (n = 75)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>MV duration</td>
<td>11 days</td>
<td>19 days</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>ICU LOS</td>
<td>14 days</td>
<td>21 days</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Hospital LOS</td>
<td>21 days</td>
<td>30 days</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Chronic care</td>
<td>24%</td>
<td>64%</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

Impact of Unplanned Extubation and Reintubation after Weaning on Nosocomial Pneumonia Risk in the Intensive Care Unit: A Prospective Multicenter Study

Lassence A. Anesthesiology 2002;97:148-56

Effect of Unplanned Extubation on Outcome of Mechanical Ventilation

SCOTT K. EPSTEIN, MICHAEL L. NEVINS, and JASON CHUNG
Pulmonary and Critical Care Division, New England Medical Center, Tufts University School of Medicine, Boston, Massachusetts


OUTCOMES

<table>
<thead>
<tr>
<th></th>
<th>Unplanned Extubation (n = 75)</th>
<th>Controls (n = 150)</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mortality</td>
<td>24 (32%)</td>
<td>45 (30%)</td>
<td>&gt; 0.2</td>
</tr>
<tr>
<td>Chronic care*</td>
<td>26 (51%)¹</td>
<td>32 (30%)</td>
<td>&lt; 0.05</td>
</tr>
<tr>
<td>Home</td>
<td>25 (49%)¹</td>
<td>73 (70%)¹</td>
<td>&lt; 0.05</td>
</tr>
<tr>
<td>Mechanical ventilation days</td>
<td>13 ± 15</td>
<td>9 ± 12</td>
<td>&lt; 0.05</td>
</tr>
<tr>
<td>ICU days</td>
<td>17 ± 16</td>
<td>12 ± 13</td>
<td>&lt; 0.05</td>
</tr>
<tr>
<td>Hospital days</td>
<td>25 ± 22</td>
<td>19 ± 18</td>
<td>&lt; 0.05</td>
</tr>
<tr>
<td>Tracheostomy</td>
<td>9 (12%)</td>
<td>12 (8%)</td>
<td>&gt; 0.2</td>
</tr>
</tbody>
</table>

Definition of abbreviation: ICU = intensive care unit.
* Rehabilitation unit, long-term acute care unit, skilled nursing facility.
† Percentages are for hospital survivors.

Impact of Unplanned Extubation and Reintubation after Weaning on Nosocomial Pneumonia Risk in the Intensive Care Unit
A Prospective Multicenter Study

Amauld de Lassennes, M.D. *, Corinne Albari, M.D., † Eric Aubay, M.D., † Jérôme Le Moine, M.D. ‡, Christelle Cheval, M.D., ‡, François Vincent, M.D., † Yves Cohen, M.D., ** Maud Garrigue-Dinges, M.D. †, Christophe Audibert, M.D. †, Gilles Triche, M.D. ‡, Jean-François Tissot, M.D., ‡, † for the OUTCOMEREA Study Group

Table 4. Duration of Mechanical Ventilation, Length of Stay, and Mortality Rate among 750 Mechanically Ventilated Patients

<table>
<thead>
<tr>
<th></th>
<th>Median (Q1–Q3)</th>
<th>Control Group (n = 150)</th>
<th>RAW + UE (n = 50)</th>
<th>P Value</th>
<th>RAW (n = 45)</th>
<th>AE (n = 22)</th>
<th>SE (n = 38)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ventilation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Duration of MV</td>
<td>7 (3–14)</td>
<td>6 (3–12)</td>
<td>17 (8–24)</td>
<td>&lt; 0.001</td>
<td>21 (14–28)</td>
<td>12 (7–16)</td>
<td>13 (5–21)</td>
<td>0.005</td>
</tr>
<tr>
<td>Cumulated MV days</td>
<td>7,953</td>
<td>8,620</td>
<td>1,933</td>
<td>1,021</td>
<td>345</td>
<td>567</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Duration of MV before event</td>
<td>—</td>
<td>5 (3–12)</td>
<td>9 (4–15)</td>
<td>4 (2–6)</td>
<td>4 (2–6)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Duration of MV after event</td>
<td>—</td>
<td>8 (4–15)</td>
<td>11 (7–16)</td>
<td>7 (5–13)</td>
<td>4 (1–13)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mortality</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ICU mortality rate</td>
<td>276 (96.9)</td>
<td>245 (88.0)</td>
<td>31 (95.5)</td>
<td>0.10</td>
<td>14 (31.1)</td>
<td>9 (40.3)</td>
<td>8 (21.1)</td>
<td>0.25</td>
</tr>
<tr>
<td>Hospital mortality rate</td>
<td>399 (43.9)</td>
<td>286 (44.2)</td>
<td>43 (41.0)</td>
<td>0.52</td>
<td>20 (44.4)</td>
<td>12 (45.5)</td>
<td>11 (29.0)</td>
<td>0.12</td>
</tr>
<tr>
<td>LOS</td>
<td>10 (6–20)</td>
<td>9 (6–17)</td>
<td>22 (11–40)</td>
<td>&lt; 0.001</td>
<td>27 (16–43)</td>
<td>19 (8–35)</td>
<td>18 (10–38)</td>
<td>0.04</td>
</tr>
<tr>
<td>ICU LOS before event</td>
<td>—</td>
<td>9 (4–16)</td>
<td>14 (8–24)</td>
<td>0.001</td>
<td>30 (16–49)</td>
<td>30 (16–49)</td>
<td>0.11</td>
<td></td>
</tr>
<tr>
<td>ICU LOS after event</td>
<td>—</td>
<td>15 (8–27)</td>
<td>16 (10–29)</td>
<td>0.001</td>
<td>30 (16–49)</td>
<td>30 (16–49)</td>
<td>0.11</td>
<td></td>
</tr>
<tr>
<td>Hospital LOS (days)</td>
<td>21 (10–37)</td>
<td>18 (8–33)</td>
<td>34 (22–64)</td>
<td>&lt; 0.001</td>
<td>38 (25–68)</td>
<td>31 (16–45)</td>
<td>30 (16–49)</td>
<td>0.11</td>
</tr>
</tbody>
</table>

RAW = reintubation after weaning; UE = unplanned extubation; AE = accidental extubation; SE = self-extubation; MV = mechanical ventilation; ICU = intensive care unit; LOS = length of stay.

Among the 750 patients, 125 (16.7%) acquired 163 episodes of nosocomial pneumonia (table 4). The crude incidence of nosocomial pneumonia was significantly higher in the patients with unplanned extubation or reintubation after weaning (36 of 105; 34.3%) than in the controls (89 of 645; 13.8%) (P < 0.01). This significant difference persisted after exclusion of nosocomial pneumonia episodes that preceded the first event (29 of 105; 27.6%; P = 0.0005).
Rescue the ETT

- **Avoid serious risks and complications related to**
  - Extubation
  - Intubation
  - ETT exchange

- Balloon-tipped catheter removal of secretions preserves pO₂ better than succioning

- No complications reported from CAM Rescue Cath™ during clinical use

**Time to Intervention**

- Reintubation and ETT exchange procedures take several minutes to set up instrumentation and actually perform once someone with intubation skills is available

- **CAM Rescue Cath™** takes seconds to set up and can be performed even by clinicians not proficient in intubation, (while someone with intubation skills is in route, in case reintubation is necessary)

**Patient Comfort Level**

- Reintubation and ETT exchange = may require sedation

- **CAM Rescue Cath™** use = no sedation needed

Which treatment alternative would most patients prefer? 😊
Poiseulle’s Equation
(Determinants of Resistance to Flow)

\[ R \propto \frac{\eta \cdot L}{r^4} \]

Resistance is inversely proportional to the radius to the 4th power.

Flow resistance determinations should also consider the effect of turbulence.

Initial contributors to turbulent flow through ETT:
- Bidirectional gas flow
- Changes in conduit direction / radius of curvature
- Changes in cross-sectional shape of conduit
- Imperfections in new conduit surface

Once a point of relative obstruction is established, flow through that orifice will be turbulent regardless of the luminal topography on either side of the obstruction.
As the ET tube lumen decreases, $WOB_{\text{Imposed}}$ increases

A decrease in diameter from 7mm to 5mm, which effectively doubles the $WOB_{\text{Imposed}}$, can result from the accumulation of secretions just 1 mm thick on the ETT lumen.

Widner & Banner, Critical Care Med 1992

Work of breathing through different sized endotracheal tubes

The ability to breathe spontaneously through an endotracheal tube is a usual prerequisite before an intubated patient can have it removed. Other researchers have measured air flow resistance through endotracheal tubes. In this study, we evaluated work of breathing in joules per min and tension-time index while three normal volunteers breathed through different sized endotracheal tubes. Four 27.5-cm endotracheal tubes were used. Subjects breathed with a constant tidal volume of 500 ml. By increasing respiratory frequency, minute ventilation was increased from 5 to 30 L/min. As tube diameter decreased, work and the tension-time index increased. Changes were magnified at higher minute ventilations through the 6- and 7-mm endotracheal tubes, and the tension-time index critical fatigue level of 0.15 was approached or exceeded.

Endotracheal tube intraluminal volume loss among mechanically ventilated patients

Chirag Shah, MD; Marin H. Kollef, MD

Table 1: Endotracheal tube volume differences according to tube size

<table>
<thead>
<tr>
<th>Endotracheal Tube Size (mm)</th>
<th>No. of Patients</th>
<th>Endotracheal Tube Volume (ml) in Unused Tubes</th>
<th>Endotracheal Tube Volume (ml) in Patient Tubes</th>
<th>Difference Between Endotracheal Tubes</th>
<th>Total Ventilation Days</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.0</td>
<td>13</td>
<td>4.4 ± 0.3</td>
<td>4.6 ± 0.6</td>
<td>0.2 ± 0.3</td>
<td>103 ± 64</td>
</tr>
<tr>
<td>5.5</td>
<td>24</td>
<td>4.6 ± 0.1</td>
<td>5.1 ± 0.5</td>
<td>0.5 ± 0.4</td>
<td>132 ± 66</td>
</tr>
<tr>
<td>6.0</td>
<td>53</td>
<td>4.6 ± 0.7</td>
<td>5.1 ± 0.6</td>
<td>0.5 ± 0.3</td>
<td>132 ± 66</td>
</tr>
<tr>
<td>6.5</td>
<td>23</td>
<td>4.6 ± 0.2</td>
<td>4.8 ± 0.8</td>
<td>0.2 ± 0.4</td>
<td>128 ± 64</td>
</tr>
<tr>
<td>7.0</td>
<td>1</td>
<td>8.2 ± 0.4</td>
<td>5.1</td>
<td>3.1 ± 0.7</td>
<td>28 ± 11</td>
</tr>
</tbody>
</table>

In summary, this study suggests that endotracheal tube narrowing and intraluminal volume loss is common among patients with acute respiratory failure. This is a potentially important observation as it suggests that weaning from mechanical ventilation can be delayed as a result of such changes in the lumens of artificial airways. In addition, we demonstrated that both the duration of mechanical ventilation and the occurrence of ventilator-associated pneumonia were associated with greater degrees of endotracheal tube intraluminal narrowing and volume loss. Based on these observations, interventional investigations seem warranted, aimed at limiting intraluminal narrowing and volume loss resulting from the accumulation of airway secretions or biofilm formation. These future studies should examine novel endotracheal tube designs and ventilation strategies aimed at limiting airway narrowing and the effect of such interventions on the duration of weaning from mechanical ventilation.

Endotracheal tube intraluminal diameter narrowing after mechanical ventilation: use of acoustic reflectometry

M. G. Boqué, B. Gualís, A. Sandiumenge, J. Reillo

Abstract

Objective: To quantify the incidence and degree of endotracheal tube intraluminal obstruction after mechanical ventilation and its relation to time of intubation. Design: Prospective observational study. Setting: A 14-bed medical-surgical intensive care unit at a university-affiliated teaching hospital. Patients: Ninety-four endotracheal tubes used in 80 patients requiring mechanical ventilation for more than 12 h. Interventions and results: Acoustic reflectometry was performed in every endotracheal tube after patient ventilation to measure its volume reduction. The intraluminal volumes of used endotracheal tubes in mechanically ventilated patients were significantly lower than those of unused tubes of the same size (5.52 ± 0.92 versus 6.54 ± 0.79 ml, p < 0.05). The mean difference in endotracheal tube segment volumes was 15.2% (range 0–65%). Volume reduction was

22% of endotracheal tubes the remaining inner diameter was less than 7 mm. Reduction below this figure was highly associated (p = 0.005). The percentage of endotracheal tube volume reduction was not associated with the duration of intubation (r = 0.09, p = n.s.). Peak pressure measured before endotracheal tube replacement was (r = 0.11, p = n.s.). Conclusions: Inadvertent endotracheal tube obstruction was common in patients requiring mechanical ventilation and may be significant as early as at 24 h. Moderate obstruction in endotracheal tube lumens should be suspected in cases of difficulties in weaning, even in patients who were ventilated for less than 1 day.

Keywords: Endotracheal tube obstruction · Reflectometry
Increases in Endotracheal Tube Resistance Are Unpredictable Relative to Duration of Intubation
Alison M. Wilson, Dana M. Gray and John G. Thomas
Chest 2009; 136:1006-1013; Prepublished online May 1, 2009; DOI 10.1378/chest.08-1938

Table 1—Percentage of Patient ETTs That Had a Measured Resistance Equivalent to a Smaller Control ETT

<table>
<thead>
<tr>
<th>Pressure Drop (cm H₂O) Equivalent to 3-SD Range of Smaller Sized Control ETT</th>
<th>30 L/min</th>
<th>60 L/min</th>
<th>90 L/min</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt; 1 size smaller (−0.5 mm ID)</td>
<td>38 (53)</td>
<td>34 (48)</td>
<td>40 (56)</td>
</tr>
<tr>
<td>&gt; 2 sizes smaller (−1.0 mm ID)</td>
<td>10 (14)</td>
<td>16 (23)</td>
<td>18 (26)</td>
</tr>
<tr>
<td>&gt; 3 sizes smaller (−1.5 mm ID)</td>
<td>4 (5)</td>
<td>7 (11)</td>
<td>11 (16)</td>
</tr>
<tr>
<td>&gt; 4 sizes smaller (−2.0 mm ID)</td>
<td>1 (1)</td>
<td>2 (3)</td>
<td>2 (4)</td>
</tr>
</tbody>
</table>

Values are given as No. (%).

Conclusions: Organized secretions can significantly increase resistance as measured by the pressure drop of ETTs. The degree of change was highly variable, occurs in all sizes, and was unrelated to the duration of intubation. The performance of an ETT may be comparable to new tubes one to four sizes smaller. This may impact the tolerance of ventilator weaning. (CHEST 2009; 136:1006–1013)

Elevated Imposed Work of Breathing Masquerading as Ventilator Weaning Intolerance
Orlando C. Kirton, C. Bryan DeHaven, Joseph P. Morgan, Jimmy Windsor and Joseph M. Civetta
Chest 1995; 108:1021-1025

Imposed work is an additional flow-resistive workload superimposed on the patient’s WOBphys. In one study, imposed work exceeded normal physiologic work by a factor of six, particularly in combination with a small ETT and high inspiratory flow rate when the patient must expend increased work to activate pressure-triggered demand-flow systems. An increase in WOBimp as a result of the added resistance of the breathing apparatus, circuit, and ETT may potentially lead to ventilatory muscle fatigue (loss of the force-generating capacity of the muscles), hypercapnia, and ultimately, respiratory failure. While the reloading of WOBimp during the weaning process by decreasing the amount of positive pressure ventilation may be tolerated by relatively healthy, short-term ventilated patients who have considerable reserve, many patients, particularly long-term ventilated patients, recovering from catabolic stress, may experience multiple weaning failures and/or trials of extubation. For these latter patients, weaning unmasked the disuse atrophy caused by catabolism and excessive ventilatory support. The additional WOBimp of the ETT, breathing circuit, and breathing apparatus at the time of weaning may be the requisite muscle load causing a failure to successfully complete the weaning/extubation trial. We suspect that the ETT represents the greatest resistance to airflow. Extubating patients sooner, even by 1 day, will decrease overall length of stay and charges, and may reduce the risk of nosocomial pneumonia, a complication linked to duration of intubation. The inference to

Conclusion: Increased WOBtot may be misinterpreted as a patient failure (ie, tachypnea) and weaning halted or extubation not done, prolonging intubation. The ability to measure the contribution of WOBimp to WOBtot can identify those patients who may be safely extubated when WOBphys (WOBtot minus WOBimp) is acceptable and the apparent ventilatory insufficiency is related to significant WOBimp. (CHEST 1995; 108:1021-25)
Endotracheal Tube Associated Pneumonia

- Civetta JM. email to PEEP Society members (2001)
  "Endotracheal Tube Associated Pneumonia (ETAP)"

  
  Noninvasive ventilation is demonstrating that the term "ventilator-associated pneumonia" is perhaps inaccurate and should be referred to as "intubation-associated pneumonia."

- Kollef, MH. SCCM 32nd Critical Care Congress (Feb., San Antonio TX): "Infection: Pneumonia", Moderator: P. Marik
  
  Dr. Kollef: "...And if I had my druthers, I think instead of calling this ventilator associated pneumonia, I’d call it endotracheal tube associated pneumonia in a large part because of the role of the endotracheal tube in both the colonization as well as in aspiration predisposition."

  
  Dr. Hess: "If the problem is the endotracheal tube, why do we keep calling it ventilator-associated pneumonia?"
  
  Dr. Macki: "That’s a very legitimate point... It would probably be more appropriate to call it endotracheal tube-associated pneumonia."

REVIEW ARTICLES

David S. Werner, M.D., and Mark A. Werner, M.D., Editors

Ventilator-associated Pneumonia or Endotracheal Tube-associated Pneumonia? An Approach to the Pathogenesis and Preventive Strategies Emphasizing the Importance of Endotracheal Tube

Ioannis A. Pneumakos, M.D., Ph.D., F.C.C.P.,* Christos K. Dragoumanis, M.D., Ph.D.,† Dencathenes E. Bouras, M.D., Ph.D., F.C.C.P.‡

Ventilator-associated pneumonia is the most common nosocomial infection in the intensive care unit, and it is associated with prolonged hospitalization, increased health care costs, and high attributable mortality. During the past several decades, numerous studies focused on the crucial role of the endotracheal tube (ETT) in the pathogenesis of ventilator-associated pneumonia. Tracheal intubation thwarts the cough reflex, compromises mucociliary clearance, injures the tracheal epithelial surface, provides a direct conduit for rapid access of bacteria from upper into the lower respiratory tract, and allows the formation of biofilm on the ETT surface. The combination of these factors puts the mechanically ventilated patient at great jeopardy of developing ventilator-associated pneumonia. Many preventive strategies have arisen from this understanding, control of intracuff pressure, aspiration of subglottic secretions, decontamination of subglottic area, use of antiseptic impregnated to 10 of ventilation, and 1% per day after this. Despite numerous original studies, reviews, and meta-analyses on pathogenesis and prevention strategies of VAP, controversies remain on these issues. This review describes current concepts and highlights the findings of recently published studies concerning the pathogenesis of VAP in relation to endotracheal tube (ETT). This may have important implications in several preventive strategies against this type of pneumonia.

We conducted a review of English language citations published in PubMed and SCOPUS without time limits until March 2008 using combinations of the following terms: pneumonia, ventilator-associated pneumonia.
Implications of endotracheal tube biofilm for ventilator-associated pneumonia

OBJECTIVE: To determine the relationship between, and antibiotic resistance of, endotracheal tube (ET) biofilm and pulmonary pathogens in ventilator-associated pneumonia.

PATIENTS: 40 intensive care unit patients - 20 with VAP, 20 without VAP as control.

MEASUREMENTS AND RESULTS: Samples of tracheal secretions were taken during ventilation for bacteriological culture. Following extubation, ETs were examined for the presence of biofilm. Where the same microorganism was found on tracheal and ET samples by phenotyping, these were confirmed as identical by genotyping and characterized for antibiotic susceptibility in both the free floating and biofilm forms.

Seventy per cent of patients with VAP had identical pathogens isolated from both ET biofilm and tracheal secretions. No pairing of pathogens was observed in control patients (p < 0.005). Susceptibility data for these pairs show that the ET acts as a reservoir for infecting microorganisms which exhibit significantly greater antibiotic resistance than their tracheal counterparts.

CONCLUSION: This investigation provides further evidence for the role of ET biofilm in VAP. The difficulty in eradicating an established microbial biofilm using antibiotics implies that increased attention must be directed towards modification of the ET to prevent or substantially reduce biofilm formation.

The concomitant development of poly(vinyl chloride)-related biofilm and antimicrobial resistance in relation to ventilator-associated pneumonia.

Ventilator-associated pneumonia is a major cause of death in intensive care patients and the endotracheal tube, commonly fabricated from poly(vinyl chloride) (PVC), is acknowledged as a significant factor in this. Bacteria colonise the biomaterial, thereby adopting a sessile mode of growth that progresses to the establishment of an antibiotic-resistant biofilm by the accretion of a protective glycocalyx. This study examined the sequential steps involved in the formation of biofilm on PVC by atomic force microscopy and the concomitant development of resistance to an antibiotic (ceftazidime) and to a non-antibiotic antimicrobial agent (hexetidine). Staphylococcus aureus and Pseudomonas aeruginosa isolated from ET tube biofilm were employed. The surface microrugosity of bacteria growing in sessile mode on PVC decreased significantly (p < 0.05) over the period 4, 24, 48 h and 5 d. The progressive accretion of bacterial glycocalyx was readily visualised in micrographs leading to a smoother surface topography with time. The minimum inhibitory concentrations (MIC) and minimum bactericidal concentrations (MBC) for ceftazidime and hexetidine against planktonic (suspension) S. aureus were lower than for Ps. aeruginosa. Furthermore, sessile populations of S. aureus and Ps. aeruginosa on PVC exhibited greater resistance to both ceftazidime and hexetidine when compared to planktonic bacterial growth. The efficacy of the agents, determined by kill kinetics, against sessile bacteria was dependent on age, with established biofilms (> or = 24 h) significantly more resistant (p < 0.05) than early sessile populations (< or = 4 h). Importantly, for practice, even newly colonised bacteria (1 h) were significantly more resistant to antibiotic than planktonic bacteria. Hexetidine was significantly more active (p < 0.05) than ceftazidime on biofilms of both isolates, irrespective of age, with total kill within 24 h treatment. Hexetidine may offer promise in the resolution of infection associated with PVC endotracheal tubes.
Guidelines for the Management of Adults with Hospital-acquired, Ventilator-associated, and Healthcare-associated Pneumonia

Infected biofilm in the endotracheal tube, with subsequent embolization to distal airways, may be important in the pathogenesis of VAP (Level III).

Statement of the 4th International Consensus Conference in Critical Care on ICU-Acquired Pneumonia -- Chicago, Illinois, May 2002

Another important site for bacterial adherence is the endotracheal tube itself, which provides a sequestered nidus of bacteria within biofilms coating the tube surface [6, 38, 78]. Furthermore, the endotracheal tube and suctioning can traumatize the tracheobronchial surface, facilitating bacterial adherence, and can promote mucus stagnation, which also favors bacterial proliferation.
Use of the **CAM Rescue Cath** and implementation of a **Rescue Loop** within a weaning algorithm facilitate adherence to these VAP prevention strategies recommended by SHEA.

**SECTION 3: STRATEGIES TO PREVENT VAP**

a. General strategies
   i. Conduct active surveillance for VAP.32,53
   ii. Adhere to hand-hygiene guidelines published by the Centers for Disease Control and Prevention or the World Health Organization.32,53
   iii. Use noninvasive ventilation whenever possible.34,61
   iv. Minimize the duration of ventilation.35,62,68
   v. Perform daily assessments of readiness to wean3,50 and use weaning protocols.75,82,64,69
   vi. Educate healthcare personnel who care for patients undergoing ventilation about VAP.52,73,76,71

b. Strategies to prevent aspiration
   i. Maintain patients in a semirecumbent position (30°-45° elevation of the head of the bed) unless there are contraindications.26,50,82,65,76,73,74
      (a) Experimental trials have demonstrated that backrest elevation is associated with a reduced risk of pulmonary aspiration.72-75
      (b) Multivariable analysis of risk factors associated with VAP found up to a 67% reduction in VAP among patients maintained in semirecumbency during the first 24 hours of mechanical ventilation.74
      (c) The impact of semirecumbency was confirmed in an observational study39 and a randomized trial.73
   ii. Avoid gastric overdistention.26,87,73,40
   iii. Avoid unplanned extubation and reintubation.2,3,52,53
      (a) Meta-analysis demonstrated that subglottic secretion drainage was effective in preventing early-onset VAP.39,40
      (b) Proximal cuff pressures no less than 20 cm H2O.36
   iv. Use a cuffed endotracheal tube with in-line or subglottic suctioning.53,81,41-46
How effective is suctioning the ET tube?

Dynamic ET Tube Obstructions

Ventilator breath

?static appearance at extubation?

functional obstruction while “in situ”
Bacterial dissemination into the lungs in ventilator-associated pneumonia

**Biofilm** lining the endotracheal tube:

- Heterogeneous layer of variable thickness, usually greatest at the lower end of the tube.
- Composed of **bacteria**, **neutrophils** in varying stages of disintegration, and an amorphous matrix, probably corresponding to respiratory **mucus**.

Represents the progressive accretion of respiratory secretions, deposited during the **repeated passage of tracheal suction catheters**.

Inglis / Journal of Hospital Infection 1995

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Nosocomial pulmonary infection: Possible etiologic significance of bacterial adhesion to endotracheal tubes

Conclusions:

- **Adhesive colonization** of long-term indwelling endotracheal tubes may be a significant factor in the pathogenesis of nosocomial pulmonary infection.

    Subsequent **dislodgment of clumps of biofilm-protected bacteria into the lungs by a suction catheter** may provide an explanation other than microaspiration for the extraordinarily high incidence of nosocomial pulmonary infection in intubated patients.

Sottile / Critical Care Medicine 1986
Endotracheal saline and suction catheters: sources of lower airway contamination

Study
- Insertion of a suction catheter and instillation of a 5 ml. saline bolus through the endotracheal tube of extubated patients who had been mechanically ventilated > 48 hrs

Results
- Suction catheter dislodged 60,000 viable bacterial colonies
- 5 ml. saline bolus dislodged 310,000 viable bacterial colonies

Conclusions
- Routine use of saline during suctioning procedures should be abandoned.

Hagler / Am J Crit Care 1994

Endotracheal Suction and Normal Saline Instillation
Scope of Practice in a Pediatric ICU: Results of a Multidisciplinary Survey

About 30% of RTs and 30% of RNs routinely perform NS instillation before ET suctioning

Reasons Why
- To break down tenacious secretions (most common)
- To lubricate the suction catheter
- To promote cough

= Intentional Iatrogenic Aspiration

Ruben D Restrepo Abstract presented at AARC 2004 meeting
OBJECTIVE: Artificial secretions were removed by suction (using 12- or 18-French suction catheters) or by means of a balloon-tipped catheter (6-French Fogarty arterial embolectomy)

SUBJECTS: 20 experiments performed on five dogs anesthetized with halothane

MEASUREMENTS: 5 ml of mucin injected 10 cm down the endotracheal tube prior to a 30-sec period of intermittent positive pressure ventilation. After this procedure, the ventilator was disconnected and the secretions were removed by suction with the 12- or 18-French catheters or by the Fogarty catheter

RESULTS: Arterial blood pressure (MAP) and pulmonary artery pressure (PAP) did not change after either technique. There were no ECG changes, arrhythmias, or alterations in PaCO₂. The PaO₂...

Leiman / Anesth Analg 1987

Removal of tracheal secretions in anesthetized dogs: balloon catheters versus suction

<table>
<thead>
<tr>
<th>Catheter Type</th>
<th>% Secretions</th>
<th>PaO₂ (mm Hg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Suction 12 Fr.</td>
<td>26</td>
<td>520</td>
</tr>
<tr>
<td>Suction 18 Fr.</td>
<td>42</td>
<td>451</td>
</tr>
<tr>
<td>Fogarty</td>
<td>90</td>
<td>564</td>
</tr>
</tbody>
</table>

“Balloon removal of tracheal secretions has two advantages over conventional suction techniques: it removes more secretions, and it has less detrimental effect on arterial oxygenation.”

Leiman / Anesth Analg 1987
Clinicians only see the ‘tip of the iceberg’ while the patient is intubated.

“We don’t have secretion-related ETT obstructions because we stay on top of the humidification issue.”

Endotracheal tube position and appearance in the clinical setting

IMPORTANT clarification: Differentiate between complete/near-complete ETT obstruction (rare) versus partial ETT obstruction (nearly ubiquitous).

These investigators reported ETT obstruction in all or nearly all ETTs.

Nosophomial pulmonary infection: Possible etiologic significance of bacterial adherence to endotracheal tubes

Scanning electron microscopy (EM) showed an amorphous accretion of material which completely covered the surface of 21 (84%) tubes and partially covered the surface of 4 (16%) tubes.

\[ 84 + 16 = 100\% \text{ tubes} \]

Rod-shaped or coccoid **bacterial profiles** within the material on the surface of 17 (68%) tubes.

Influence of selective decontamination of the digestive tract on microbial biofilm formation on endotracheal tubes from artificially ventilated patients

- “Extensive biofilm formation by scanning electron microscopy on 97% of tubes examined.”
- “This persistent nidus may be a factor in the pathogenesis of nosocomial pneumonia.”

These prominent intensivists described the problem as a **COMMON / FREQUENT** one and also report on its adverse clinical impact.

**Dr. Marin Kollef**, Crit Care Med 2004

In summary, this study suggests that endotracheal tube narrowing and intraluminal volume loss is common among patients with acute respiratory failure. This is a potentially important observation as it suggests that weaning from mechanical ventilation can be delayed as a result of such changes in the lumens of artificial airways. In addition, we demonstrated

**Dr. Jordi Rello**, Intens Care Med 2004

\( r=0.11; p=\text{n.s.} \) **Conclusions:** Inadvertent endotracheal tube obstruction was common in patients requiring mechanical ventilation and may be significant as early as at 24 h. Moderate obstruction in endotracheal tube lumens should be suspected in cases of difficulties in weaning, even in patients who were ventilated for less than 1 day.

**Dr. Alison Wilson**, Chest 2009

Conclusions: Organized secretions can significantly increase resistance as measured by the pressure drop of ETTs. The degree of change was highly variable, occurs in all sizes, and was unrelated to the duration of intubation. The performance of an ETT may be comparable to new tubes one to four sizes smaller. This may impact the tolerance of ventilator weaning.

Have you done a study in your ICU? You probably have the same problem and are unaware of it.
These prominent thought leaders and others agree that endotracheal tube narrowing by secretions:

- is a **“common”** clinical occurrence in their own state-of-the-art ICUs
- can lead to **“difficulties”** and **“delays”** in weaning patients from mechanical ventilation
- is **not accounted for or offset** by compensatory mechanisms (such as ATC) programmed into ventilator settings
“Exactly which patients need ‘Rescuing’?”

“Rescue” Cath™ applies to rescuing patients ‘complete’ ETT obstruction and rescuing patients from failed weaning trials due to elevated WOB_{imp}.

R.E.S.C.U.E. acronym for airway management
- Remove
- Endotracheal tube
- Secretions
- Comprehensively
- Until
- Exubation

RECOMMEND keeping CAM Rescue Cath™ ‘within arms reach’ = at the bedside for patients with ETT
- In emergent cases → Ensures immediate availability
- In cases of ‘failure to wean’ → Visual reminder of WOB_{imp} “Rescue”

Guidelines for use of the CAM Rescue Cath™

CAM Rescue Cath™ use as a Therapeutic Tool — Target Patient Population
Use of the CAM Rescue Cath™ in specific clinical scenarios may help prevent the need for emergent extubation or ETT exchange and/or facilitate the weaning of specific subsets of failure-to-wean patients.
1. Sudden ETT occlusion manifested by: tachypnea, hypoxia, hypertension or hypotension, bradycardia, restlessness, diaphoresis, chest retractions, use of accessory breathing muscles, cyanosis.
2. Need to replace a vent circuit component due to mechanical malfunction or soiling from secretions
3. Resistance to passage of a suction catheter through the ETT.
4. Frequent or recurrent ventilator alarms related to high peak pressures.
5. Lower O₂ saturations not attributed to worsening respiratory disease or CXR.
6. Decrease in tidal volume ventilator readings.
7. Need for FiO₂ or pressure support increase over a given time.
8. Duration of intubation exceeds that anticipated by severity of illness.
9. History of suctioning for previous or current blood or blood clots.
10. Respiratory secretions classified as moderately thick to thick.
11. Patient ventilated in the prone position.
13. Characteristic ‘square pressure/volume tracing on ventilator graphics display.
14. Measured elevation in pressure drop across the ETT or elevation in WOB_{imp}.
15. Bronchoscopy (direct visual) confirmation of ETT lumen narrowing by secretions.
16. Patient classified as ‘failure-to-wean’ from mechanical ventilation.

RECOMMEND keep CAM Rescue Cath™ ‘within arm’s reach’ at bedside of patients with an ETT, in code carts and difficult airway carts to ensure immediate availability in life-threatening cases.

CAM Rescue Cath™ use as Diagnostic Tool
Ventilator weaning trial or pre-extubation assessment. Use of the CAM Rescue Cath™ may:
1. Rule out ETT occlusion due to secretions in failure-to-wean cases. If significant secretions are not retrieved, ‘failure-to-wean’ is probably not related to elevated WOB_{imp} due to ETT occlusion.
2. Rule in (and resolve) ETT occlusion by luminal secretions as cause of ‘failure-to-wean’ if secretions are retrieved and significant decrease WOB_{imp} is noted (identified by resolving signs of respiratory distress and improving O₂ sat, RR, HR, BP. Peak Pressures. Tidal Volumes).

CAM Rescue Cath™ use as Procedure Facilitation Tool
Bronchoscopy or Percutaneous Tracheostomy. Use of the CAM Rescue Cath™ prior to these may:
1. Facilitate ease and reduce the risk of passing the bronchoscope through the ETT by removing mucus that can be pushed into the bronchi, potentially inoculating them with a microbial bolus.
2. Facilitate a quicker procedure by improving visualization through and beyond ETT.

ETT exchange for ETT cuff leak. Use of the CAM Rescue Cath™ prior to this may:
1. Facilitate ease and reduce the risk of passing the ETT exchange catheter through the ETT by removing mucus that can be pushed into the bronchi, inoculating them with a microbial bolus.
2. Help ensure the ETT exchange catheter lumen and the ETT lumen area between the ETT and ETT exchange catheter will remain as patent as possible during procedure.
“What percent of MV patients are at risk for failure to wean due to ET tube secretions and elevated WOB_{imp}?”

Based on the direct measurements taken by Kaufman (medical, surgical, trauma, burn patients) 8% of patients had ‘moderate’ (25-49%) ETT obstruction, 17% had severe (50-74%) ETT obstruction and 11% had very severe (75-100%) ETT obstruction (total of mod. - very sev. = 36%; total of sev. - very sev. = 28%)

Based on the acoustic reflectometry data reported by Rello (medical, surgical, trauma patients) looking at ET tube secretions reducing ET tube diameter to <7 mm, 22% of all patients studied are at risk for failure to wean.

Based on the WOB clinical practice data reported by Kirton (trauma, surgical patients), 18% of patients were clinically categorized as failure-to-wean and they actually had elevated WOB_{imp} as the cause of their weaning failure.

Average of the findings is that greater than 20% of patients at risk for suffering ‘failure to wean’ due to partial ETT obstruction from secretions.


“Will my patients wean faster or be extubated sooner after their ETT is cleaned and WOB_{imp} reduced?”

This will depend on several factors:

Has their WOB_{Disease} (and / or the problem they were intubated for) resolved?
• The Rescue Cath does not address WOB_{Disease}.

How long have they been intubated, and has their MV support been appropriately titrated to specifically offset their WOB_{Disease} + WOB_{Imposed} (eg. Not excessive MV support)?
• Excessive MV support for prolonged periods of time can potentially ‘decondition’ the respiratory muscles, which would require re-conditioning through a slower weaning process in order to achieve liberation from MV support

How aggressively will they be ‘weaned’/extubated?
• If the dials on the vent are not manually turned down on a regular basis, no degree of clinical improvement will result in the actual reduction of MV support.
“How long after intubation should I start thinking about cleaning the ETT (day 3, day 4…)?”

Dr. Alison Wilson, Chest 2009

One of the most unexpected results of the study was the lack of relationship found between the duration of intubation and the degree of increased resistance. A previous study has suggested that increases were associated with a longer period of intubation (>7 days). Our data showed that differences in pressure drop were unpredictable events. Notably, there was a significant number with marked increases in resistance but short intubation times. A very high increase was found in an ETT from a patient who had been intubated for only 3 h; conversely, an ETT from a patient intubated for 300 h had measurements equivalent to those of size-matched controls. This demonstrates that this is not simply a time-related event. A possible limitation of

Dr. Jordi Rello, Intens Care Med 2004

(r=0.11, p=n.s.) Conclusions: Inadvertent endotracheal tube obstruction was common in patients requiring mechanical ventilation and may be significant as early as at 24 h. Moderate obstruction in endotracheal tube lumens should be suspected in cases of difficulties in weaning, even in patients who were ventilated for less than 1 day.

Based on these results…

ANSWER: Day 1

Comparative Anatomy: Natural Airway versus Artificial Airway

This “most important first line of defense” is iatrogenically nullified by and when the patient is intubated, so when (from the ethical perspective & pathophysiological standpoint) when should clinicians start thinking about cleaning the ETT?

Based on the basic pathophysiology…

ANSWER: Hour 1
"We'd have to break the circuit, which we don't like to do."

There are 2 main reasons why clinicians don't want to open or 'break' the circuit:
1. Don't want to increase risk of pneumonia to patient.
2. Don't want to lose PEEP.

If the clinician doesn't want to increase risk of pneumonia to patient, you can point out:
1. Colonization sequence studies have shown a retrograde sequence that does not support the concept of inoculating the patient by breaking the circuit.
2. Prospective randomized trials comparing open (breaking the circuit) with closed suction clinical practice do not show any difference in VAP between groups.

The presence and sequence of endotracheal tube colonization in patients undergoing mechanical ventilation

First Part
13 patients with nosocomial pneumonia
8 patients with matching pathogens in lower respiratory secretions & ET tube

Second Part
Site | Timing (hours)
--- | ---
ET tube | 60-96
Lower resp. tract | 60-84
Stomach | 36-80
Oropharynx | 36

Endogenous source of bacteria in tracheal tube and proximal ventilator breathing system in intensive care patients

- 20 patients in SICU with daily cultures taken from each of 6 sites
- Findings implied a "retrograde route" of bacterial colonization of the ventilated lung extending into the proximal respiratory breathing system

First Isolated (day)

<table>
<thead>
<tr>
<th>Site</th>
<th>Range</th>
<th>Median</th>
</tr>
</thead>
<tbody>
<tr>
<td>Y-Piece</td>
<td>4-9</td>
<td>7.0</td>
</tr>
<tr>
<td>Expiratory Trap</td>
<td>1-9</td>
<td>5.0</td>
</tr>
<tr>
<td>Angle Piece</td>
<td>1-9</td>
<td>3.5</td>
</tr>
<tr>
<td>ET tube lumen</td>
<td>1-8</td>
<td>2.0</td>
</tr>
<tr>
<td>Gastric Aspirate</td>
<td>1-6</td>
<td>1.0</td>
</tr>
<tr>
<td>Suction Catheter</td>
<td>1-4</td>
<td>1.0</td>
</tr>
</tbody>
</table>


Impact of the suctioning system (open vs. closed) on the incidence of ventilator-associated pneumonia: meta-analysis of randomized controlled trials

- Metanalysis of 9 randomized controlled trials
- 644 patients
- VAP in 128 (20%) of the patients with open suction
- VAP in 120 (19%) of the patients with closed suction
- "At a given pneumonia prevalence of 20% in ICU patients there was no significant advantage for the use of either suctioning system…"
Discussions regarding ‘opening / breaking the circuit’ should always include a clarification of the following:

- the CDC guidelines that outline when the circuit breaks are justified, which correlate with both the indications for use of the CAM Rescue Cath™ and the methodology by which it removes ETT secretions
- studies comparing open vs. closed system care strategies
- the risks of alternative interventions for ETT secretions:
  - saline irrigation of the ETT
  - weaning intolerance (partial ETT obstructions)
  - emergent extubation (severe ETT obstructions)
3. Breathing circuits, humidifiers, and heat- and moisture exchangers (HMEs)

   a. Breathing circuits with humidifiers

      1) Do not change routinely, on the basis of duration of use, the breathing circuit (i.e., ventilator tubing and exhalation valve and the attached humidifier) that is in use on an individual patient. Change the circuit when it is visibly soiled or mechanically malfunctioning (IA) (30–35).

      2) Breathing-circuit–tubing condensate

         a) Periodically drain and discard any condensate that collects in the tubing of a mechanical ventilator, taking precautions not to allow condensate to drain toward the patient (IB) (30).

         b) Wear gloves to perform the previous procedure and/or when handling the fluid (IB) (37,38,39).

         c) Decontaminate hands with soap and water (if hands are visibly soiled) or with an alcohol-based hand rub after performing the procedure or handling the fluid (IA) (38,39).

   3) No recommendation can be made for placing a filter or trap at the distal end of the inspiratory–expiratory tubing of the breathing circuit to collect condensate (Unresolved issue).

   4) Humidifier fluids

      a) Use sterile (not distilled, nonsterile) water to fill bubbling humidifiers (II) (36,40–43).

      b) No recommendation can be made for the preferential use of a closed, continuous-feed humidification system (Unresolved issue).

   b. Ventilator breathing circuits with HMEs

      1) No recommendation can be made for the preferential use of either HMEs or heated humidifiers to prevent pneumonia in patients receiving mechanically assisted ventilation (Unresolved issue) (IB) (44–49).

      2) Changing HME

         a) Change an HME that is in use on a patient when it malfunctions mechanically or becomes visibly soiled (II).
“Will it penetrate a mucus plug?”

• Design factors
  • 8 Fr. catheter body / ~12 Fr. catheter tip at cleaning assembly = narrower than typical 14 Fr. suction catheter used in adults
  • Higher durometer = more pushability than typical suction catheter
  • Mushroom tip = glide through secretions rather than pushing them ahead of itself

• It will likely follow an ETT insertion path previously kept patent by the suction catheter, and which only very recently became completely occluded.

• It has not failed in its task to remove a mucus plug or blood clot and restore ETT patency in clinical practice.

“Will it push ETT secretions into trachea?”

• About 200 ETTs tested on bench with no evidence of CAM Catheters dislodging or pushing secretions down the ETT
• Consider the RELATIVE RISK of NOT removing secretions
  • Leave a larger amount to serve as a larger bolus
  • Can get dislodged by
    • Ventilator breath
    • Saline irrigation
    • Instrumentation
      • Suction catheter
      • Bronchoscope
      • ET exchange catheter

“Will it score the ET tube?”

• The cleaning assembly on the Rescue Cath™ looks like a metallic stent, but the mesh is plastic (just like the ETT is plastic) and should not score it, especially given the limited force that can be applied between the contact surfaces by way of the inflated balloon.

• There has been no evidence of any ETT becoming scored during bench-testing of about 200 ETTs.