Clinical Indicators for Endotracheal Suctioning in Adult Patients Receiving Mechanical Ventilation

By Mary Lou Sole, RN, PhD, CCNS, Melody Bennett, RN, MN, CCRN, and Suzanne Ashworth, RN, MSN, CCRN, CCNS

Background
Critically ill patients who need mechanical ventilation require endotracheal suctioning. Guidelines recommend coarse crackles over the trachea and/or the presence of a sawtooth pattern on the flow-volume loop of the ventilator waveform as the best indicators.

Objective
To determine clinical cues for endotracheal suctioning in patients who require mechanical ventilation.

Methods
A descriptive study of 42 adult patients receiving mechanical ventilation. After baseline endotracheal suctioning with a closed-system device, patients were assessed hourly up to 4 hours for guideline-based cues for endotracheal suctioning and lung sounds were auscultated. Endotracheal suctioning was done when cues were detected or 4 hours after baseline suctioning. Secretions were collected, measured, and weighed.

Results
Most patients were male (62%) and white (93%). Mean age was 51 years, and mean duration of mechanical ventilation was 7.5 days. The median time to endotracheal suctioning was 2 hours, and a mean of 4.4 mL of secretions was removed. Three patients had no cues identified but had 1.0 mL or more of secretions. The most frequent cues were crackles over the trachea (88%), sawtooth waveform (33%), coughing (29%), and visible secretions (5%). Cues resolved and physiological parameters improved after suctioning. Coarse lung sounds did not improve.

Conclusions
Patients receiving mechanical ventilation should be routinely assessed for coarse crackles over the trachea, the most common indicator for endotracheal suctioning. Despite common practice, assessment of lung sounds to identify the need for suctioning is not supported.

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Critically ill patients treated with mechanical ventilation require an artificial airway, either an endotracheal tube or a tracheostomy tube. These patients often retain tracheobronchial secretions because of impaired cough reflex, decreased mucociliary clearance, and, possibly, increased mucus production. Endotracheal suctioning is essential to remove retained tracheobronchial secretions, and nurses and respiratory care practitioners assume the responsibility for removal. The 2010 clinical practice guidelines for endotracheal suctioning of the American Association of Respiratory Care specify that endotracheal suctioning should be done when clinically indicated rather than routinely and give 10 indicators for the suctioning (Table 1).

The sawtooth waveform and coarse crackles over the trachea reportedly are the most sensitive indicators of the need for suctioning. Yet in practice, most health care providers rely on auscultation of lung sounds (rather than tracheal sounds) to assess the need for, and response to, endotracheal suctioning. Therefore, the purpose of this study was to identify which assessments best indicate the need for endotracheal suctioning.

Background

Although endotracheal suctioning is essential, it should be done only as needed because the procedure can result in hypoxemia, dysrhythmias, or damage of the tracheal mucosa. Indications for endotracheal suctioning have been studied by only a few researchers. In 1976, Amborn published the results of an assessment of 22 clinical signs that might indicate the presence of secretions, which were defined as a volume of secretions 0.5 mL or greater obtained via open suctioning methods 1 hour after a baseline suctioning procedure. The volume of secretions retrieved ranged from 0.0 mL to 5.5 mL. After preliminary analysis, Amborn narrowed the signs to 15 (including increased body temperature; increases or decreases in pulse, respiratory rate, systolic blood pressure, diastolic blood pressure, ventilator system pressure, or tidal volume; coarse breath sounds; and prolonged expiratory sounds). She found that a change of 5 mm Hg in systolic or diastolic blood pressure was a significant predictor of secretions \((P = .02-.07)\). She also reported that the number of signs present was associated with the volume of secretions.

The presence of a sawtooth pattern on ventilator waveform recordings was first reported in 1994 by Jubran and Tobin. In a sample of 50 ventilator-dependent patients with a tracheostomy, a sawtooth waveform on the flow-volume loop (observed via an external apparatus) had high sensitivity (0.76-0.86) and specificity (0.86-0.90) for detection of secretion during a 1-minute period of spontaneous breathing. Guglielminotti et al conducted a follow-up study to identify factors indicative of retained secretions and the need for endotracheal suctioning in patients receiving mechanical ventilation. Need for suctioning was defined as retrieval of 0.5 mL or more of secretions during suctioning. A sawtooth pattern on the flow-volume loop waveform together with coarse crackles over the trachea were the best indicators of retained secretions. Guglielminotti et al

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**Table 1**

| Recommendations for endotracheal suctioning from the American Association of Respiratory Care

<table>
<thead>
<tr>
<th>Condition</th>
<th>Indicator</th>
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<tbody>
<tr>
<td>Sawtooth pattern on flow-volume loop on ventilator monitor</td>
<td></td>
</tr>
<tr>
<td>Coarse crackles auscultated over trachea</td>
<td></td>
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<tr>
<td>Increased peak inspiratory pressure during volume control ventilation</td>
<td></td>
</tr>
<tr>
<td>Decreased tidal volume during pressure-controlled ventilation</td>
<td></td>
</tr>
<tr>
<td>Deterioration in oxygen saturation and/or arterial blood gas values</td>
<td></td>
</tr>
<tr>
<td>Visible secretions in airway</td>
<td></td>
</tr>
<tr>
<td>Patient’s inability to generate an effective cough</td>
<td></td>
</tr>
<tr>
<td>Acute respiratory distress</td>
<td></td>
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<tr>
<td>Suspected aspiration of gastric or upper airway secretions</td>
<td></td>
</tr>
</tbody>
</table>

*Based on information from the clinical practice guidelines from the American Association of Respiratory Care.*

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**About the Authors**

Mary Lou Sole is Orlando Health Distinguished Professor and Pegasus Professor, University of Central Florida, College of Nursing, Orlando, Florida, and a research scientist at Orlando Health, Orlando, Florida. Melody Bennett is a member of the adjunct faculty at the University of Central Florida and a clinical research coordinator at Orlando Health. Suzanne Ashworth is a clinical nurse specialist in neurological critical care at Orlando Regional Medical Center, Orlando, Florida.

**Corresponding author:** Mary Lou Sole, RN, PhD, CCNS, CNL, FAAN, FCCM, Orlando Health Distinguished Professor and Pegasus Professor, University of Central Florida, College of Nursing, 12201 Research Pkwy #300, Orlando, FL 32826-2210 (e-mail: mary.sole@ucf.edu).
also concluded that the absence of a sawtooth pattern on the ventilator flow-volume loop waveform can be used to rule out retained secretions.

Wood conducted a study to identify differences in the outcomes of endotracheal suctioning between patients who had routine (every 2 hours) suctioning and those who had suctioning based on the results of nurses’ assessments. Endotracheal suctioning was done every 2.6 hours in the assessment group and every 2.1 hours in the routine group. Compared with patients in the routine group, patients in the assessment group had significantly more secretions retrieved per suctioning episode and a greater reduction in peak airway pressure after the procedure. Assessment indicators most often used by the nurses were chest sounds (crackles, gurgles, and wheezes) detected via auscultation and coughing. Other clinical indicators were recorded in documentation notes (oxygen desaturation, changes in arterial blood gases, and increased peak airway pressure), but these cues were not used by the nurses to determine the need for endotracheal suctioning. A limitation of Wood’s study is that neither aspiration over the trachea nor inspection of ventilator waveforms was included in the nursing assessment. Additionally, no minimum amount of secretions was defined as indicating the need for suctioning. Higher secretion volumes in the assessment group compared with the routine group may have been due to the longer time between suctioning episodes in the assessment group.

Endotracheal suctioning may also improve outcomes or reduce complications, such as ventilator-associated pneumonia. Caruso et al found that routine suctioning based on indications described in the guidelines of the American Association of Respiratory Care, along with instillation of physiological saline, reduced the risk for ventilator-associated pneumonia by 54% in a sample of critically ill patients. The authors hypothesized that suctioning and/or coughing induced after the instillation of physiological saline may have contributed to the reduced risk for infection. Blamoun et al included regular endotracheal suctioning, defined as suctioning every 4 hours, as part of an expanded ventilator bundle and were successful in reducing the rates of ventilator-associated pneumonia to zero. However, which intervention contributed to the reduction in the rate of pneumonia is not known.

Sole and Bennett assessed the practices of nurses and respiratory care practitioners regarding endotracheal suctioning. A total of 85 participants in the study, mostly experienced providers, listed assessments the participants used to determine the need for endotracheal suctioning. The 2 most frequent responses were an increase in peak inspiratory pressure or an alarm indicating an increase (69%) and detection of rhonchi over the lung fields via auscultation (66%). Only 14% listed a sawtooth pattern on the respiratory waveform as an indicator, and no one listed detection of coarse crackles over the trachea via auscultation. Generalizability of the results were limited because all the responses were from experienced providers in a single hospital system.

Endotracheal suctioning is considered a necessary procedure for patients with artificial airways. Recommendations for identifying the need for endotracheal suctioning have been developed by professional societies but may not be widely incorporated. In clinical practice, a variety of assessments are used to determine the need for suctioning, primarily auscultation for detection of abnormal sounds. The purpose of this study was to expand on the work of others to help determine the best practices for assessing the need for endotracheal suctioning.

**Methods**

**Design**

A descriptive, comparative study design was used. The study was approved by the appropriate institutional review boards of the hospital and university. Each patient’s legal proxy provided consent for the patient’s participation in the study.

**Setting and Sample**

The study was conducted in the critical care units (medical-surgical, trauma, and neurological) at a tertiary care hospital in the Southeastern United States. A convenience sample of patients receiving mechanical ventilation was recruited for participation. Patients were included in the study if they were adults (18 years or older) who were treated with traditional mechanical ventilation with a ventilator waveform display available. The target sample size was 66 patients to compare the study findings with those of Guglielminotti et al. However, the study was ended after 43 patients because of consistent patterns noted during data collection.

**Procedures**

Demographic data were obtained from the electronic medical records. After a patient was enrolled in the study, baseline suctioning was done with the closed-system suction device after hyperoxegenation with 100% oxygen via the ventilator. Immediately before and after the baseline suctioning, physiological
data were recorded from bedside monitors and the ventilator and digital photographs of the ventilator waveform were obtained.

After baseline suctioning, each patient was assessed every hour by 1 of 2 investigators (M.L.S. or M.B.) by using a checklist derived from the American Association for Respiratory Care guidelines. Tracheal auscultation was done above the sternum, and the presence or absence of coarse crackles was noted during the expiratory phase of ventilation. Lung sounds were also assessed via auscultation because that practice is common. Interrater reliability was established between investigators during simultaneous assessment of 5 patients. The ventilator waveforms routinely monitored were the scalars for flow, volume, and pressure rather than the flow-volume loop. Because the flow-time scalar waveform is commonly used in practice and can be used to identify obstruction to flow in the airways, this waveform was used for detection of a sawtooth pattern. Physiological data and digital photographs of the ventilator waveform tracings were obtained hourly. When an indication for endotracheal suctioning per the checklist was identified, suctioning via a closed-system device was performed. Suctioning passes were repeated until the investigator deemed that secretions were retrieved. Physiological data, peak inspiratory pressure, and waveform images were recorded before and after the suctioning. Additionally, secretions obtained during endotracheal suctioning were weighed and measured. If no cues were identified within 4 hours after the baseline suctioning, endotracheal suctioning was performed and volume and weight of the secretions was recorded. The photographs of the respiratory waveforms were reviewed independently by 3 investigators to determine the presence or absence of a sawtooth pattern, a pattern similar to that seen in atrial flutter cardiac rhythms. A sawtooth pattern was deemed present when all investigators agreed on its identification on the image. Figures 1A and 2 show the presence of a sawtooth pattern, which is especially prominent in Figure 2.

Results

Demographic Data

A total of 43 patients were enrolled in the study between June and December 2012. One patient was extubated during data collection and so the patient’s data were excluded from analysis, yielding a final sample size of 42. Most of the patients were male (62%), were white (93%), and had an admitting diagnosis of trauma (60%). Mean age was 51 (SD, 21) years, and the mean duration of mechanical ventilation was 7.5 (SD, 6.1) days. The majority of patients (83%) had volume synchronized intermittent mandatory ventilation; others were on assist-control (10%) or pressure support (7%) ventilation. Median ventilator settings included tidal volume 700 mL, set respiratory rate 2/min, positive end-expiratory pressure 5 cm H₂O, pressure support 10 cm H₂O, and fraction of inspired oxygen 0.35. The median score on the Glasgow Coma Scale was 10, and the median score on the Sedation Agitation Scale was 3. Among the patients, 52% had a heat-moist exchanger for humidification, and 48% had a heated circuit.
Table 2
Changes in physiological parameters before and after suctioning

<table>
<thead>
<tr>
<th>Variable</th>
<th>Before Suction</th>
<th>After Suction</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak inspiratory pressure, cm H₂O</td>
<td>23.2</td>
<td>21.8</td>
<td>.001</td>
</tr>
<tr>
<td>Oxygen saturation, %</td>
<td>95.3</td>
<td>96.7</td>
<td>&lt;.001</td>
</tr>
</tbody>
</table>

*Mandatory breath for those on synchronized intermittent mandatory ventilation or assist-control ventilation only (n= 31).*

Suctioning Data

The median time to endotracheal suctioning was 2 hours (range, 1-4 hours). A total of 2 to 4 suctioning passes were needed to clear secretions; the mean was 2.5 (SD, 0.6) passes, and the median was 2.0. The volume of secretions ranged from 1.0 to 15.0 mL; mean volume was 4.4 (SD, 3.2) mL, and the median was 3.5 mL. The mean weight of secretions was 3.3 (SD, 3.1) g, with a median of 2.6 g. The correlation between secretion volume and weight was 0.93 (P = .01).

Improvement After Suctioning

Repeated-measures statistics were used to assess improvement after suctioning. A paired-sample t test was used to assess physiological characteristics before and after suctioning. Peak inspiratory pressure was lower and oxygen saturation was increased after suctioning (Table 2). A related sample McNe mar test was used to compare presence or absence of cues before and after suctioning. After suctioning, absence of a sawtooth waveform (P < .001; Figure 1B), no cracks over the trachea (P < .001), and no cough (P < .001) were noted, indicating removal of secretions. No difference was noted in visible secretions before or after suctioning (P = .50). Lung sounds did not improve after suctioning. Both before and after suctioning, 45% of the patients had rhonchi, coarse lung sounds, or both (P > .99).

Additional Findings

Because 3 patients had no cues, demographic data and volume of mucus between patients with and without cues were compared. Nonparametric statistics indicated no significant differences across demographic variables.

An independent-samples t test was used to compare volume of mucus retrieved with the type of ventilator humidification. The 20 patients who had a heated circuit had 4.8 mL of mucus retrieved, whereas the 22 patients who had a heat-moisture exchanger had 4.2 mL retrieved (P = .56). Additionally, the percentage of patients with a sawtooth pattern did not differ according to type of humidification. A sawtooth pattern was detected in 30% of the patients with a heated circuit and in 36% of the patients with a heat-moisture exchanger (χ² analysis: P = .66).

Discussion

Suctioning was indicated a median of 2 hours after the baseline suctioning. This finding agrees with the results of Guglielminotti et al. All of our patients, including the 3 who had no assessment cues, had 1.0 mL or more of secretions suctioned. This threshold was higher than that set by Amborn, Jubran and Tobin, and Guglielminotti et al who used a threshold of 0.5 mL or greater. We chose the 1-mL value because measuring smaller amounts in the specimen traps was difficult. We found that weight of secretions can be used as a proxy for volume (we found a high correlation between volume and weight) as reported previously.

Mean volume of secretions was higher in our patients than in the patients of Guglielminotti et al. We did not use suctioning until cues were identified, a practice that may account for the higher volume of secretions. Wood found a higher volume of secretions when suctioning was done on the basis of nurses’ assessments rather than routinely. Our patients received mechanical ventilation for a mean of 7.5 days, compared with 4.6 days for the patients in the study by Guglielminotti et al, and had humidification of the ventilator circuit. Either of these factors could have been a reason for our higher volume of secretions.

We detected coarse crackles over the trachea in 88% of our patients, a higher percentage than the 67% reported by Guglielminotti et al. The larger volumes of secretions retrieved in our patients may be a cause for the increase in the number of patients with audible crackles over the trachea.

We identified a sawtooth pattern on the ventilator waveform in only 33% of our patients, whereas
Guglielminotti et al detected a sawtooth pattern in 88%. Perhaps the flow-time waveform is not as sensitive as the flow-volume loop waveform for detecting this pattern. However, we wanted to use standards of care for respiratory monitoring in force at the clinical site so that the findings could be applied in practice; therefore, we used the flow-time waveform for assessment. We found no differences in sawtooth patterns between type of humidification.

Our patients were receiving mechanical ventilation via 3 different ventilators: Avea (CareFusion), Bear 1000 (CareFusion), and Evita (Draeger). Waveforms were slightly different on each type (Figure 2). The Avea ventilator had the clearest waveforms for visualization and assessment. We classified a pattern as sawtooth only if it clearly showed oscillations (Figure 1A and Figure 2). Many patients had a wavy waveform (Figure 1B). We did not classify this pattern as a sawtooth. Although we attempted to empty moisture from the ventilator circuit, small amounts of water could result in a wavy flow-time waveform (Figure 1B).

Additionally, our patients differed from those in other studies. Compared with our patients, the patients in the study of Guglielminotti et al2 were older, predominately had respiratory failure, and had been receiving mechanical ventilation for a shorter time. Our patients were younger trauma patients who had been receiving mechanical ventilation for a longer period. Although our patients had stable ventilator settings, they had respiratory failure that required prolonged mechanical ventilation. Their physiological conditions may have resulted in greater production of secretions.

Similar to the results of Wood,4 improvements in peak inspiratory pressure and oxygen saturation occurred with suctioning. Although statistically significant, the changes were small and may not be important clinically. However, our results show the impact of suctioning on physiological parameters.

Although our findings were not statistically significant, we found that the volume of secretions increased with the number of cues identified. This finding compares favorably with results reported by Amborn,5 who noted that the number of signs (although different from ours) was associated with secretion volume. Wood6 also found a higher volume of mucus when suctioning was done according to the results of nurses’ assessments.

Despite common practice,7 assessment of lung sounds is not a good method for detecting a need for suctioning. Nearly half of our patients had rhonchi or coarse breath sounds over the lung fields both before and after suctioning. Endotracheal suctioning retrieves secretions primarily from the upper part of the airway above the carina. Secretions in the lower parts of the airway that may result in coarse breath sounds are not retrieved. Therefore, despite common practice, breath sounds would not necessarily improve after suctioning.

Our study had limitations. Patients received mechanical ventilation via 3 different ventilators with different quality and depiction of waveforms, and we looked solely at the flow-time scalar. Comparing simultaneous tracings of the flow-time scalar and the flow-volume loop waveforms for presence of a sawtooth pattern would also be important. Ventilation modes and humidification varied; a more homogeneous group of patients might yield better data to guide practice. Our patients had been intubated for a mean of more than a week. Findings might be different in patients who were intubated for only a few days compared with findings in patients who had refractory respiratory failure or lung injury that requires a longer duration of mechanical ventilation. Studying patients over the course of mechanical ventilation would yield rich data. None of our patients were given paralytic medications. Patients treated with paralytic agents are an important group to study because they might not have some cues, such as coughing.

Additional research is needed to identify the optimal frequency of assessments to guide suctioning. Data are also needed to determine the optimal timing for suctioning when no cues are detected.

Because patients should receive suctioning only when needed in order to prevent complications from the procedure, the right assessments must be done to determine the need for suctioning. On the basis of our data, we recommend incorporating assessment of the ventilator waveform and auscultation over the trachea as part of the assessment for suctioning done every 2 to 4 hours. The presence of a sawtooth pattern on a patient’s flow-time waveform should alert a nurse or respiratory care practitioner to further assess the patient for the need for suctioning. The patient should also be assessed for physiological changes, such as high-pressure alarms, cough, and visible secretions. Not all ventilators have a display of the waveform; therefore, assessments that rely on readily available data are just as important as those that rely on technology. Additionally, nurses generally rely on respiratory care practitioners to manage the ventilator and may need some basic knowledge of waveform analysis.

FINANCIAL DISCLOSURES
None reported.
REFERENCES


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