

A Bedside Decision Tree for Use of Saline With Endotracheal Tube Suctioning in Children

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BACKGROUND Endotracheal tube suctioning is necessary for patients receiving mechanical ventilation. Studies examining saline instillation before suctioning have demonstrated mixed results.

METHODS A prospective study to evaluate whether saline instillation is associated with an increased risk of suctioning-related adverse events in patients 18 years old or younger requiring mechanical ventilation through an endotracheal tube for at least 48 hours when suctioned per protocol using a bedside decision tree.

RESULTS A total of 1986 suctioning episodes (1003 with saline) were recorded in 69 patients. The most common indication for use of saline was thick secretions (87% of episodes). In 586 suctioning episodes, at least 1 adverse event occurred with increased frequency in the saline group ($P < .001$). Normal saline was more likely to be associated with hemodynamic instability ($P = .04$), bronchospasm ($P < .001$), and oxygen desaturation ($P < .001$). Patient factors associated with adverse events include younger age ($P < .001$), a cuffed endotracheal tube ($P = .001$), endotracheal tube diameter of 4.0 mm or less ($P < .001$), respiratory or hemodynamic indication for intubation ($P < .001$), underlying respiratory disease ($P < .001$), and longer duration of mechanical ventilation ($P < .001$). Saline instillation ($P < .001$), endotracheal tube size of 4.0 mm or less ($P = .03$), and comorbid respiratory diseases ($P = .03$) were associated with an increased risk of adverse events.

CONCLUSIONS Saline instillation before endotracheal tube suctioning is associated with hemodynamic instability, bronchospasm, and transient hypoxemia. Saline should be used cautiously, especially in children with a small endotracheal tube and comorbid respiratory disease. (*Critical Care Nurse*. 2016;36[1]:e1-e10)

Because of changes in respiratory mechanics and mucociliary function, intubated patients have impaired ability to clear airway secretions¹ and often require suctioning via their endotracheal tube to remove sputum in an effort to prevent occlusion and ventilator-associated infections. Specific indications for suctioning the endotracheal tube include coarse crackles over the trachea, increased peak inspiratory pressure or decreased tidal volume, oxygen desaturation, and acute respiratory distress.² It is hypothesized that instilling saline before suctioning the endotracheal tube may help remove retained pulmonary secretions by liquefying mucus, stimulating a vigorous cough, and preventing encrustation of the endotracheal tube.³

Studies of the effectiveness and safety of this practice have demonstrated varied results concerning overall sputum retrieval, hemodynamic tolerance, and relationship with ventilator-associated infections. In a systematic review of 17 studies that met inclusion criteria, Paratz and Stockton⁴ found minimal evidence of either a benefit or a risk when saline was used for suctioning in terms of hemodynamic, respiratory, neurological, and patient comfort parameters. Only 4 studies included neonates or children.

Of studies in children, researchers in 1 study⁵ reported no change in sputum production when normal saline was instilled via an endotracheal tube in 8 neonates. Two studies^{6,7} of neonates (25 patients in 1 study⁶ and 18 patients in the other⁷) demonstrated no differences in hemodynamic tolerance when saline was instilled before the endotracheal tube was suctioned. In 9 neonates with respiratory distress syndrome, Beeram and Dhanireddy⁷ showed a decrease in oxygen saturation (95% at 10 minutes before suctioning vs 87% at time of

suctioning with saline, $P < .05$) that returned to normal within 10 minutes of the episode. Ridling et al⁸ also demonstrated transient oxygen desaturation with saline instillation. In this study of 24 children, a percentage change in oxygen saturation from baseline was noted at 1, 2, and 10 minutes. Saline instillation, when compared with dry suctioning, was associated with a larger decrease from baseline at 1 minute (5.7% vs 1.5, $P = .01$) and at 2 minutes (4.8% vs 1.0%, $P = .005$). However, at 10 minutes, oxygen saturation did not differ between the 2 groups. One study⁹ ($n = 86$) demonstrated a benefit of increase in the time to endotracheal tube occlusion (77.6 vs 13.5 hours, $P < .05$) when saline was instilled via a small (2.5 mm) endotracheal tube; another study⁸ showed no benefit of saline when compared with dry suctioning.

Because of the lack of evidence of a direct benefit and evidence that saline instillation may increase the risk of adverse events, the American Thoracic Society¹⁰ and the American Association for Respiratory Care² recommend that the routine use of saline with endotracheal tube suctioning be avoided in both adults and children.

Bedside caregivers within our pediatric intensive care unit (PICU) use a decision tree (Figure 1), based on these recommendations and the Institute for Healthcare Improvement's 100 000 Lives Campaign (2005) to reduce ventilator-associated pneumonia (VAP), to guide the use of normal saline when suctioning intubated patients. Indications include the presence of an ineffective cough or concern for mucus plugging that may result in endotracheal tube occlusion. We tracked the use of saline for suctioning episodes in our PICU and recorded specific adverse events that occurred in association with suctioning to evaluate the hypothesis that saline use is associated with an increased rate of adverse events for the patient when compared with dry suctioning.

Materials and Methods

This prospective observational study explores the use of a bedside decision tree in endotracheally intubated infants and children admitted to the Just For Kids Critical Care Center (JFKCCC) at Kosair Children's Hospital in Louisville, Kentucky. The JFKCCC is a 26-bed intensive care unit located within a free-standing tertiary care pediatric hospital. Patients met inclusion criteria if they were no more than 18 years of age, admitted to the PICU, and required mechanical ventilation through an endotracheal tube for at least 48 hours.

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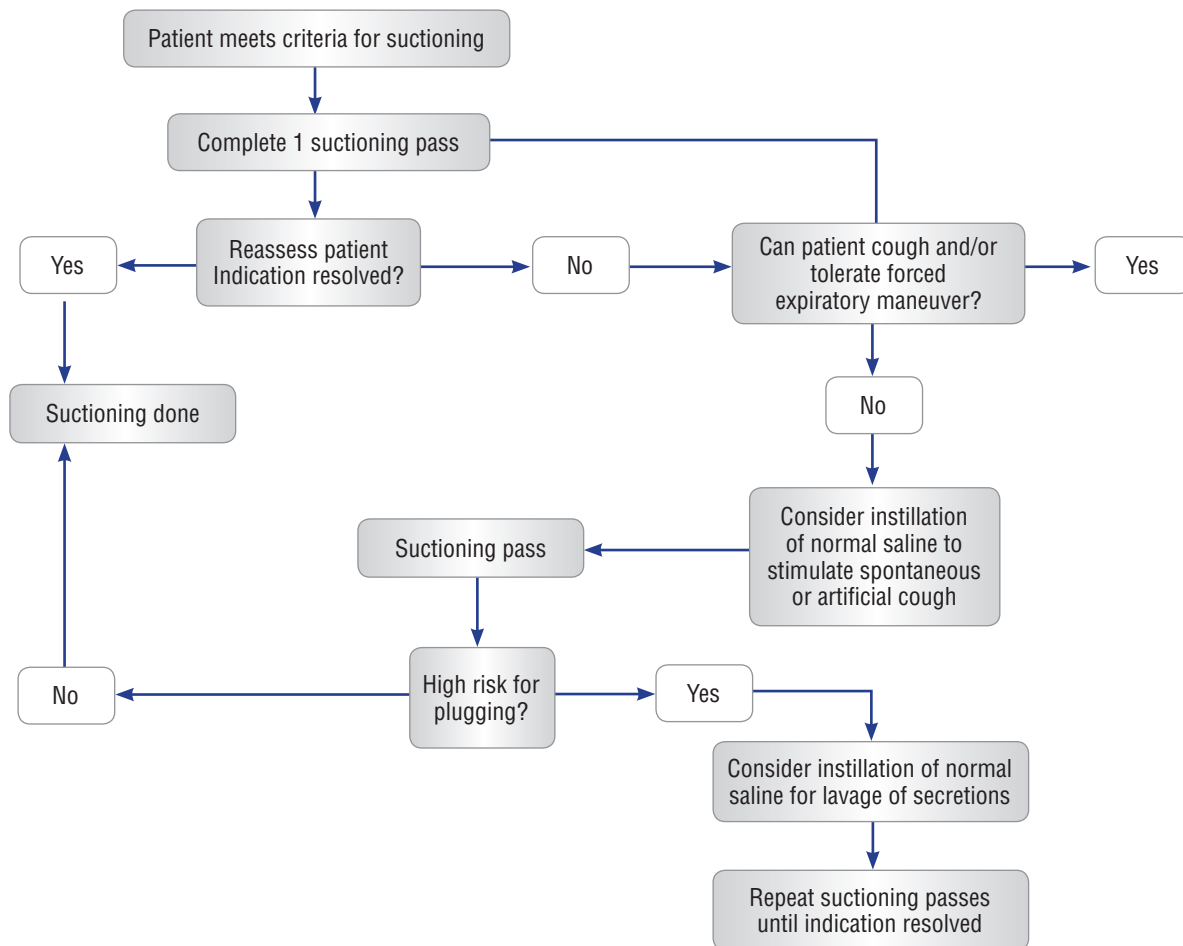


Figure 1 Decision tree for normal saline instillation. Based on Children's Hospital of Boston Medical/Surgical Intensive Care Unit Practice Guidelines, Institute for Healthcare Improvement Campaign to Save 100,000 Lives, Pediatric Node, July 2005.

Demographic information obtained for each patient included age, sex, endotracheal tube size, the presence of a cuffed endotracheal tube, duration of mechanical ventilation, length of PICU stay, Pediatric Index of Mortality 2 (PIM2) score,¹¹ primary reason for intubation (hemodynamic instability, trauma, respiratory disease, neurological disease, or out-of-hospital cardiac arrest), location of intubation (PICU, other unit within the hospital, or outlying hospital), and whether the patient had a pulmonary comorbid condition such as asthma or chronic lung disease.

Suctioning Protocol

Upon study entry, the bedside caregiver continued to suction the endotracheal tube per unit protocol and used the saline decision tree to determine if saline was warranted

for each suctioning pass. In our unit, nurses have the ability to suction outside of the decision tree in extenuating circumstances such as suspected occlusion of the endotracheal tube or as a rescue maneuver in the context of acute hypoxemia or hypercarbia. Impending occlusion of the endotracheal tube was suspected if there was an abrupt decrease in breath sounds, a change in the end-tidal carbon dioxide waveform, a loss of inspired tidal volume, or an increase in peak pressure on the ventilator.

If criteria were met for suctioning with saline (Figure 1), then generally 1 to 2 mL of normal saline, from a prepackaged vial, was instilled into the endotracheal tube and suctioning was performed. The suctioning protocol includes hyperoxygenation at a minimum of 10% above the patient's baseline unless contraindicated, suctioning pressures of 80 to 120 mm Hg depending on

the patient's age, and brief (10-15 second) shallow suctioning passes. The standard method of suctioning in our PICU is a closed technique that allows the patient to remain connected to the ventilator while an in-line suctioning catheter (Kimberly-Clark Ballard) is passed through the endotracheal tube. Saline can then be instilled via a side port if warranted. An open technique is occasionally used. This involves disconnecting the patient from the ventilator, manually ventilating the patient with either an anesthesia or bag valve mask attached to the endotracheal tube, and then suctioning the endotracheal tube with a separate sterile catheter. Saline is instilled directly into the endotracheal tube if necessary.

Following each suctioning pass that occurred after the patient had been intubated for 48 hours, bedside caregivers recorded the time, date, and primary reason for saline instillation: either extrapolated through the "high risk for plugging" branch point of the decision tree (subjectively thick secretions or the inability to remove secretions without saline), physician request, or suspected occlusion of the endotracheal tube. Use of saline and any adverse events that occurred during or within a 10-minute period immediately following the suctioning episode were recorded. Four types of adverse events were captured: hemodynamic instability, bronchospasm

Desaturation was the most common adverse event, followed by bronchospasm and hemodynamic instability.

requiring unexpected bronchodilator use, oxygen desaturation defined as oxygen saturation shown by

pulse oximetry (SpO_2) less than or equal to 90% (or 5% below patient's baseline), and failure of SpO_2 to return to baseline within the 10-minute window after suctioning. Hemodynamic instability was determined at the nursing level. If the patient had changes in hemodynamic status related to the suctioning episode that prompted the nurse to engage the physician at the bedside, an adverse event was recorded. The study period concluded when the patient was extubated. Patients reentered the study (as a new participant) if they were extubated for more than 1 hour before reintubation and remained intubated for at least 48 additional hours.

Complications associated with mechanical ventilation were noted for each patient and included VAP and ventilator-associated lower respiratory tract infection as defined by the Centers for Disease Control and Prevention,¹² endotracheal tube occlusion defined as

suspected obstruction requiring removal of the tube, and unplanned extubation as tracked by research nurses for all intubated patients.

Confidentiality

This study was reviewed and approved by the institutional review board at the University of Louisville. It was approved as an exempt quality improvement project that did not require informed consent for enrollment.

Statistical Analysis

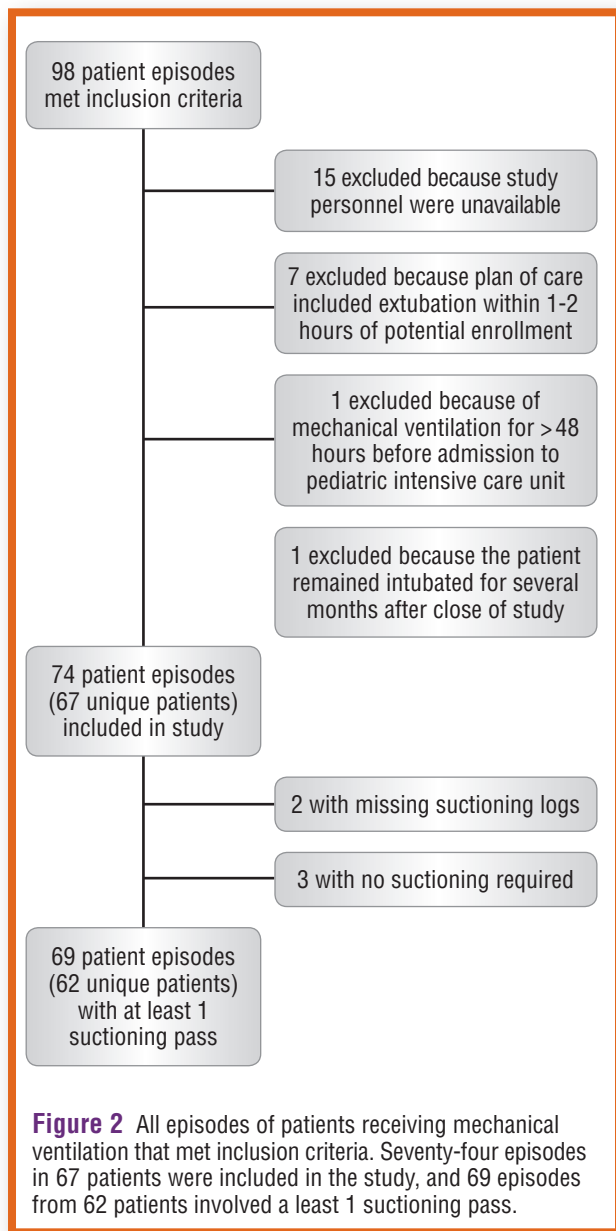
Descriptive analysis of the analytic sample was performed for the individual patients ($n=69$) and at the level of suctioning episode ($n=1986$). Means and standard deviations were calculated for continuous variables, whereas frequencies and proportions were calculated for categorical data. Spearman correlation coefficients were calculated to explore relationships between continuous variables. Chi-squared tests were used to test associations between categorical variables. Mann-Whitney tests were used to test associations between categorical and continuous variables.

Two-level logistic regression modeling was used to further explore the association of use of saline for suctioning episodes with adverse events to account for potential nonindependence of the suctioning episodes at the patient level. This analysis was conducted by using the Complex Samples module of SPSS version 22 (IBM SPSS, IBM Corp), where the variable patient was set as the unit of clustering.

Results

Participants

During the study period, 98 patient ventilation episodes met inclusion criteria; 74 episodes (67 patients) were enrolled in the study and 69 episodes (62 patients) had at least 1 suctioning pass after a minimum of 48 hours of mechanical ventilation (Figure 2). Five patients were enrolled more than once (3 patients twice; 2 patients 3 times). Table 1 lists the demographic information for study participants. The mean patient age was 4.2 (SD, 5.2) years. For all ventilator patient episodes, 74% involved intubation with a cuffed endotracheal tube, more than half (51%) were intubated outside of the PICU, hemodynamic instability was the most common indication for intubation (42%), and approximately one-third of patients had underlying lung disease.



Mean length of stay in the PICU was 16 (SD, 10) days with a mean of 7.5 (SD, 5.9) days of mechanical ventilation. Mean probability of death based on PIM2 severity of illness scores (probability of death = $\exp(\text{PIM2 score}) / [1 + \exp(\text{PIM2 score})]$)¹¹ was 19% (SD, 27%).

Suctioning Episodes

In 1986, a total of 1990 documented suctioning episodes during this study had complete bedside caregiver documentation. The rate of completed documentation did not differ between suctioning episodes that used saline (1003, 50.5%) and those that did not (983, 49.5%). The mean number of suctioning episodes per enrollment

was 29 suctioning passes, with approximately half performed with saline (Table 1). Indications given for saline instillation were as follows: thick secretions (87%), followed by the inability to remove secretions without saline (6%), suspected occlusion of the endotracheal tube (2%), and physician request (<2%). Data on the indication for saline use were missing for 3%. A total of 53 suctioning episodes (3%) were performed as a rescue maneuver in the patient, with saline used 34 times (64%) for this indication. An adverse event occurred with 26% of suctioning passes. Desaturation was the most common adverse event (18%), followed by bronchospasm (11%) and hemodynamic instability (0.5%; Table 1).

Adverse Events

One or more adverse events (hemodynamic instability, bronchospasm, oxygen desaturation, and failure of SpO_2 to return to baseline) were noted in 586 suctioning passes and were more frequent in the saline group than in the dry suctioning group (39.3% vs 19.5%, $P < .001$; Table 2). Hemodynamic instability (1.2% vs 0.3% of episodes, $P = .04$), bronchospasm (17.6% vs 7.1% of episodes, $P < .001$) and oxygen desaturation (26% vs 13.5% of episodes, $P < .001$) were more frequent when saline was used than when it was not. Failure of oxygen saturation recovery within 10 minutes after suctioning was higher in the saline group, but the difference was not statistically significant ($P = .27$, Table 2).

Patient factors associated with adverse events during suctioning are shown in Table 3. Patient age was lower among suctioning episodes with an adverse event (mean of 2.4 vs 3.5 years, $P < .001$). The presence of a cuffed endotracheal tube ($P = .001$) and an endotracheal tube diameter of 4.0 mm or less ($P < .001$) were both more common among suctioning episodes with an adverse event. The primary indication for intubation also was associated with adverse events during suctioning. For example, if a patient was intubated for respiratory illness, an adverse event occurred during approximately 30% of suctioning episodes as compared with a patient intubated for trauma—only 2% of suctioning passes had an adverse event noted ($P < .001$). Underlying respiratory disease was present more often among suctioning episodes with an adverse event (42% vs 33%, $P < .001$). Patients with suctioning episodes associated with an adverse event had a longer duration of mechanical ventilation (mean of 14.7 vs 12.4 days, $P < .001$).

Table 1 Characteristics of the 69 episodes of mechanical ventilation in 62 patients whose endotracheal tube suctioning episodes were included in this study

Characteristic (categorical)	No. (%) ^a	Characteristic (continuous)	Mean (SD); median (IQR)
Sex		Age, years	4.2 (5.2); 1.4 (0.15-8.0)
Female	34 (49)		
Male	35 (51)		
Endotracheal tube cuffed		Days of mechanical ventilation	7.5 (5.9); 6.0 (3.6-8.8)
Yes	51 (74)		
No	18 (26)		
Endotracheal tube diameter, mm		Days in pediatric intensive care unit	16 (10); 14 (7.6-22)
≤4.0	43 (62)		
≥4.5	26 (38)		
Intubated		Probability of death score, %	19 (27); 6 (3-26)
In pediatric intensive care unit	18 (26)		
In another unit	35 (51)		
Outside the hospital	16 (23)		
Comorbid respiratory disease		Number of suctioning episodes per patient	29 (41); 18 (8.5-34)
Present	22 (32)		
Absent	47 (68)		
Intubation indication		Percentage of suctioning episodes with saline	49 (29); 45 (30-67)
Hemodynamic instability	29 (42)	Percentage of suctioning episodes with any adverse event	26 (26); 22 (2-41)
Trauma	9 (13)		
Respiratory disease	16 (23)		
Neurological disease	6 (9)		
Out-of-hospital cardiac arrest	9 (13)		
Ventilator-associated complications		Percentage of suctioning episodes with hemodynamic instability	0.5 (2); 0 (0-0)
Pneumonia	2 (3)	Percentage of suctioning episodes with bronchospasm	11 (19) 0 (0-22)
Lower respiratory tract infection	2 (3)	Percentage of suctioning episodes with oxygen desaturation	18 (22); 12 (0-25)
Endotracheal tube occlusion	2 (3)		
Unplanned extubation	1 (1)		

Abbreviation: IQR, interquartile range.

^a Seven patients are included more than once in these summary data.**Table 2** Association of adverse events with saline use among 1986 episodes of endotracheal tube suctioning^a

Event type	No. (%) of suctioning episodes			P ^b
	Total (N=1986)	Saline use (n=1003)	No saline (n=983)	
Any adverse event	586 (29.5)	394 (39.3)	192 (19.5)	<.001
Bronchospasm	247 (12.4)	177 (17.6)	70 (7.1)	<.001
Hemodynamic instability	15 (0.8)	12 (1.2)	3 (0.3)	.04
Oxygen desaturation	394 (19.8)	261 (26.0)	133 (13.5)	<.001
Persistent desaturation ≥10 minutes ^c	34/393 (8.7)	26/261 (10.0)	8/132 (6.1)	.27

^a Some suctioning episodes were associated with more than 1 type of adverse event.^b P values determined by χ^2 test.^c Denominators represent number of desaturation events.

The frequency of adverse events also varied by indication for saline use within this group of suctioning events (Table 3). Saline use for presence of thick secretions in the endotracheal tube (the most common

indication) was somewhat underrepresented (83% vs 90%) and the indication no results without saline was more frequent (8.6% vs 4.4%) in the adverse event group ($P < .001$).

Table 3 Associations of patient characteristics and indications for saline use during suctioning with any adverse events associated with suctioning by individual suctioning episodes^a

Characteristics	Total episodes (N=1986)	Any adverse event related to suctioning		P ^b
		Yes (n=586)	No (n=1400)	
Endotracheal tube cuffed				.001
Yes	1626 (81.9)	506 (86.3)	1120 (80.0)	
No	360 (18.1)	80 (13.7)	280 (20.0)	
Intubation indication				<.001
Hemodynamic instability	1004 (50.6)	332 (56.7)	672 (48.0)	
Trauma	154 (7.8)	12 (2.0)	142 (10.1)	
Neurological conditions	145 (7.3)	28 (4.8)	117 (8.4)	
Respiratory disease	421 (21.2)	175 (29.9)	246 (17.6)	
Out-of-hospital cardiac arrest	262 (13.2)	39 (6.7)	223 (15.9)	
Comorbid respiratory disease				<.001
Present	712 (35.9)	247 (42.2)	465 (33.2)	
Absent	1274 (64.1)	339 (57.8)	935 (66.8)	
Endotracheal tube diameter, mm				<.001
≤4.0	1455 (73.3)	489 (83.4)	966 (69.0)	
≥4.0	531 (26.7)	97 (16.6)	434 (31.0)	
Sex				.06
Female	1066 (53.7)	334 (57.0)	732 (52.3)	
Male	920 (46.3)	252 (43.0)	668 (47.7)	
Age, mean (SD); median (interquartile range), y	3.20 (4.70); 0.75 (0.24-3.64)	2.41 (4.33); 0.75 (0.23-1.46)	3.53 (4.81); 0.75 (0.24-6.0)	<.001 ^c
Days of mechanical ventilation, mean (SD); median (interquartile range)	13.1 (8.4); 10.2 (6.9-20.1)	14.7 (9.2); 10.8 (6.4-25.0)	12.4 (7.9); 10.0 (7.0-17.1)	<.001 ^c
Indications for saline use during suctioning event	n=1003	n=394	n=609	.001
Thick secretions	875 (87.2)	326 (82.7)	549 (90.1)	
Provider request	16 (1.6)	5 (1.3)	11 (1.8)	
Suspected occlusion of endotracheal tube	22 (2.2)	9 (2.3)	13 (2.1)	
No results without saline	61 (6.1)	34 (8.6)	27 (4.4)	
Missing data for indication	29 (2.9)	20 (5.1)	9 (1.5)	

^a Numbers in second through fourth column are number (percentage) of patients unless otherwise indicated in the first column.

^b P values represent χ^2 results unless otherwise indicated.

^c Mann-Whitney tests for difference in distributions.

Multivariable Analysis of Any Adverse Event During Suctioning

Two-level logistic regression modeling was performed to account for clustering of data at the ventilation episode level (69 episodes in 62 patients) to further evaluate whether saline instillation was independently associated with adverse events (Table 4). Three factors remained associated with adverse events: saline instillation (odds ratio, 2.78; 95% CI, 1.79-4.32; $P < .001$), an endotracheal tube size of 4.0 mm or less (odds ratio, 2.90; 95% CI, 1.13-7.45; $P = .03$), and the presence of a comorbid respiratory disease (odds ratio, 1.78; 95% CI, 1.06-2.99; $P = .03$). Sex, age, the presence of a cuffed endotracheal tube, reason for intubation, and duration of mechanical

ventilation did not remain associated with adverse events. Because thick secretions were the indication for use of saline in 87% of the suctioning events in this group, saline indication subsets were not included in the multivariable analysis.

Discussion

We found a concerning frequency of adverse events associated with all suctioning episodes as well as with saline suctioning events in our sample of pediatric patients. We believe ours is the first pediatric study to demonstrate a significant increase in the risk of clinically significant hemodynamic deterioration requiring physician intervention after a saline suctioning pass.

Table 4 Association of saline use for 1986 suctioning episodes with any adverse event after adjusting for other factors in 2-level logistic regression modeling that accounted for clustering of data at the patient level (N = 69)^a

Factor	Complex sample logistic regression			
	Odds ratio	95% CI		P
		Lower	Upper	
Saline used for suctioning (vs no saline)	2.78	1.79	4.32	<.001
Endotracheal tube size ≤4.0 mm (vs ≥4.5 mm)	2.90	1.13	7.45	.03
Comorbid respiratory disease (vs none)	1.78	1.06	2.99	.03
Female (vs male)	0.73	0.41	1.28	.26
Cuffed endotracheal tube (vs noncuffed)	2.90	1.13	7.45	.34
Intubated for hemodynamic instability or pulmonary disease (vs other)	1.31	0.94	1.81	.10
Days of mechanical ventilation ^b	1.00	0.97	1.03	.90
Age, ^b y	0.98	0.89	1.09	.74

^a Hosmer and Lemeshow test = 0.60 for standard logistic regression model that used same variables with similar results for saline use.

^b Odds ratio indicates change per unit of measurement (eg, odds ratio for 12 days of ventilation versus 6 days = 1.004).⁶

This study is also the first to report a significant increase in the unexpected use of bronchodilators when saline is used, suggesting that saline may be an airway irritant causing bronchospasm immediately following a suctioning pass. Our study also identified potential risk factors for suctioning-related adverse events including saline instillation, endotracheal tube diameter of 4.0 mm or less, and the presence of a comorbid respiratory disease.

This study is one of the largest to date in children, and we believe it is the first to quantify the number of suctioning passes per day along with the frequency of saline administration in intubated patients when a bedside decision tree is used. As expected, suctioning of the endotracheal tube continues to be a significant component of patient care within our PICU, with

Saline should be used cautiously, especially in young children with a small ETT and comorbid respiratory disease.

approximately 5 suctioning passes per patient per day that an endotracheal tube is in place. Furthermore, saline is used in approximately 50% of all suctioning passes, with thick secretions being the most common indication for the use of suctioning.

In the 2010 clinical practice guidelines of the American Association for Respiratory Care,² the authors warn of hazards associated with endotracheal tube suctioning, including changes in lung compliance, capacity, and volume; hypoxia; trauma; bronchospasm; and hemodynamic instability. Our study confirms that endotracheal tube

suctioning is indeed associated with risk for deterioration in the patient's condition. On average, a patient experienced an adverse event with 26% of suctioning passes whether or not saline was instilled. Although not all possible complications were evaluated, we did note that oxygen desaturation was the most likely adverse event, followed by bronchospasm and hemodynamic deterioration. Although most of these events were limited, they could prove catastrophic in patients intubated for hemodynamic instability where equilibrium is already tenuous.

Our study further demonstrates a significant increase in adverse events (oxygen desaturation, hemodynamic instability, and bronchospasm) when suctioning with saline was chosen over dry suctioning, which holds true even with logistic regression modeling. Many adult studies have demonstrated significant decreases in oxygenation when saline is administered just before a suctioning pass. In the one randomized controlled pediatric study, Ridling et al⁸ noted a significant decrease in SpO₂ (approximately 5% vs 1%) at 1 and 2 minutes after a suctioning pass with saline compared with dry suctioning passes; however, no difference in SpO₂ was noted at 10 minutes after suctioning. Our findings support these data in that significantly more suctioning passes were associated with oxygen desaturation when saline was used, but there was no sustained difference in oxygen saturation 10 minutes after the suctioning episode occurred, suggesting a very limited effect.

We also identified 2 additional patient factors after multivariate adjustment (including clustering at the

patient level) that may contribute to suctioning-related adverse events. Only a small endotracheal tube and the presence of a comorbid respiratory disease continued to be associated with adverse events, although that association was not as significant as that for saline instillation.

It is unclear why a smaller endotracheal tube would increase the risk of adverse events. Although smaller endotracheal tubes would be associated with younger patients, age does not appear to be an independent risk factor for adverse events. Perhaps because tubes with smaller diameters also have shorter lengths and therefore a narrower window of accurate measured suctioning before the carina is stimulated, patients with these tubes would be at higher risk for agitation leading to desaturation, bronchospasm, and possible hemodynamic instability. Further studies are needed to address this.

It is not surprising that patients with an underlying comorbid respiratory disease at the time of intubation would be at higher risk for adverse events with suctioning. Patients with underlying asthma and chronic lung disease are at high risk for bronchospasm and hypoxia with very little stimulus.

Previous studies have had mixed results concerning the impact that saline instillation has on the rate of complications associated with mechanical ventilation such as ventilator-associated infections and occlusion of the endotracheal tube. In vitro studies have suggested that instillation of saline may actually increase the risk of ventilator-associated infections by dislodging significantly more viable bacteria¹³ and exposure to contaminated saline vials.¹⁴ One recent study¹⁵ in adults showed fewer cases of microbiologically proven VAP when saline instillation occurred before suctioning (relative risk reduction, 54%) and no association between saline use and endotracheal tube obstruction. Other respiratory interventions such as physiotherapy may have contributed to a reduction in their VAP rate.¹⁶ In the only pediatric study⁹ to date in which rates of endotracheal tube occlusion were measured as a primary outcome, when a very small (2.5-mm) endotracheal tube was used, saline instillation was associated with an increased mean time to endotracheal tube occlusion (13.5 vs 77.6 hours, $P < .05$).

During our study period, very few ventilator-associated complications occurred, consistent with our unit's low rates for VAP (2.26/1000 ventilator days in 2012) and unplanned extubation (0.52/100 ventilator days in 2012) with only 5 endotracheal tube changes per year

for suspected tube occlusion. With so few events during the study period, we were unable to evaluate the potential role that instillation of saline might play in the development of these ventilator-associated complications.

This study has several limitations. First, this study design is observational and the suctioning episodes were not independent. There is also potential for confounding by indication, in that the use of saline for suctioning episodes is specified for certain clinical indications that may themselves increase the risk of adverse events with suctioning. This limitation was most likely partially offset by the inherent subjectivity of several of the algorithm-based indications. Nurses and respiratory therapists were not monitored when administering saline, and adherence to the

algorithm was not tracked. Nonetheless, the large number of suctioning events in the study, the number of other covariates assessed, the 2-level logistic regression design to adjust for cluster impacts at the ventilation episode (patient) level, and the relatively large signal magnitude of the association of saline with adverse events with suctioning lend credence to our findings. With only 69 patient episodes analyzed in the study representing 545 ventilator days and no power analysis, only 20% of all ventilator days (up to 2500) reported in our PICU were evaluated, and we cannot exclude a degree of selection bias.

Saline use nearly doubled (50% vs 25% in an unpublished unit survey performed less than a year prior) within our unit during the study period (after the algorithm was instituted). Training about suctioning practice did not change during the study period, and it is unlikely that admitting diagnoses or severity of illness changed drastically in this period to account for a perceived increase in the need for saline. It is unclear if caregivers perceived an expectation to use saline more frequently during the study period.

Conclusions

We demonstrate that saline use for endotracheal tube suctioning is associated with adverse events such as hemodynamic instability, bronchospasm, and transient hypoxemia. Additionally our findings revealed that endotracheal tubes of 4.0 mm or less and comorbid respiratory diseases increased a patient's risk of

We believe this is the first pediatric study to show a significant increase in hemodynamic deterioration with saline suctioning.

experiencing an adverse event during suctioning. Clinical decision trees and algorithms are commonplace in PICUs, and practitioners rely on them to inform safe medical management. Our findings suggest that if the saline arm of the decision tree is chosen, patients are at increased risk of an adverse event during suctioning. Perhaps other techniques such as humidified gases and chest physiotherapy should be used before administration of saline. If saline is administered, it should be used cautiously, and the bedside caregiver should be vigilant in monitoring for adverse events. Further studies are needed to delineate the benefit versus harm of saline instillation and alternative approaches to airway clearance for patients undergoing mechanical ventilation. **CCN**

Financial Disclosures
None reported.

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