Endotracheal Suctioning of the Critically Ill Child

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Abstract

Keywords

- endotracheal suction
- suctioning
- child
- neonate
- critically ill
- pediatric intensive care

Endotracheal suctioning is an essential intervention for the care of an intubated child and is one of the most commonly performed interventions in pediatric intensive care. Despite this, much of the research related to endotracheal suctioning is dated and the bulk of it conducted in preterm infants and adults. This paper will review research related to endotracheal suctioning that involves or relates to children in intensive care to provide a current review of the literature in this field. It will conclude with recommendations for practice where possible and identify areas for further research.

Introduction

Endotracheal suctioning is one of the most commonly performed nursing interventions in the pediatric intensive care unit (PICU) and is an essential procedure for any intubated child.¹ It is a complex procedure that is still poorly understood, with much of the research confined to adults and preterm infants. The aim of endotracheal suctioning is to remove secretions while minimizing any adverse effects. To achieve this, PICU nurses must be aware of the best evidence pertaining to infants and children. This paper will review research related to endotracheal suctioning that involves or relates to children in intensive care to provide a current review of the literature in this field. It will conclude with recommendations for practice where possible and identify areas for further research.

Search Strategy

A literature search was undertaken using the Parahoo² framework. Search terms were “suction”; “endotracheal suction”; “child”; “pediatric”; “pediatric,” “neonate,” and “intensive care” in July to September 2014. Databases searched were the Cochrane Library, Medline 1966 to 2014, CINAHL 1982 to 2014, PubMed Central, Proquest, Google Scholar, and Science

Direct. Reference lists from key articles were reviewed. The search was limited to published articles, in English language. ►**Fig. 1** shows a flowchart of the literature search. Inclusion criteria were: (1) experimental, quasi-experimental, or observational research designs where endotracheal suction was analyzed as the main aim or part of the study aim; (2) the research was in term neonates and children up to 17 years old (not preterm infants or adults); (3) laboratory or bench studies were included if they used endotracheal tube (ETT) sizes relating to term infants or children (size 3.0 mm ETT to size 7.0 mm ETT); (4) surveys, observational, and qualitative studies relating to suctioning practices in PICU; (5) animal studies including young animals or with ETT sizes suitable for children and term infants; and (f) limited to year 1980 and beyond.

This review is based on 43 original papers including 2 systematic reviews. Review of the papers was undertaken by two reviewers (L. N. T. and B. C.), both using a critiquing framework described by Parahoo.²

Results

The Impact of Endotracheal Suctioning in PICU Patients

Several studies have examined the physiological impact of suctioning in specific patient groups, but first an overview of

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Fig. 1 Flowchart of literature search.

the physiological impact of suctioning will be presented. Segar et al³ investigated the mechanics of the hemodynamic changes in infants during suctioning by studying the autonomic nervous system response in nine newborn lambs pre- and postvagotomy. They found that, after vagotomy, suctioning produced no changes in any parameter (heart rate [HR], mean arterial pressure [MAP], and renal sympathetic nerve activity [RSNA]). Suctioning prior to this produced significant reductions in HR, with significant elevations in MAP and RSNA. Administration of atropine blocked the HR response, but did not alter MAP or RSNA. They concluded that suctioning stimulates the sympathetic-excitatory receptors in the large airways, whose afferent fibers travel with the vagus nerve, causing increased sympathetic activity inducing peripheral vasoconstriction, thus elevating MAP.

The impact of endotracheal open suctioning on respiratory mechanics (lung compliance, tidal volume, and airway resistance) has been studied prospectively in 78 PICU children.⁴ The children included had a median age of 3.3 months (range: 0.3–25 months) and all had an ETT diameter of ≤ 4.0 mm; children with air leaks $>20\%$ were excluded, leaving only 54 infants, predominantly with pneumonia (78%) but also other conditions.⁴ They found suctioning caused an overall reduction in lung compliance ($p \leq 0.001$) and exhaled tidal volume ($p \leq 0.03$) with no change in ETT leak. Despite this reduction in compliance during suctioning, most patients' compliance increased by 31% after suctioning. A later study⁵ in six infant piglets (intubated with a size 4.0 mm ETT) has also found that suctioning causes a transient loss of end-expiratory lung volume and tidal volume throughout the lung.

Children with Traumatic Brain Injury and Raised Intracranial Pressure

Three papers have examined the impact of suction in children with traumatic brain injury (TBI). Fisher et al⁶ first

investigated the mechanism behind the raised intracranial pressure (ICP) elevation during suctioning in nine children with raised ICP. They found that the ICP elevation was related to tracheal stimulation (by the suction catheter) rather than a rise in partial pressure of carbon dioxide caused by apnea alone. Others⁷ have tried to mediate this ICP rise with suctioning by giving both intravenous and endotracheally administered lidocaine to nine adolescent (and some adult) patients with severe TBI. They found both administration methods reduced ICP with suctioning, but administration by the endotracheal route was more effective at suppressing ICP elevation. This supports Fisher's⁶ findings that the mechanism of ICP elevation with suctioning in this group of children is caused primarily by tracheal stimulation. A further observational study of 25 children with severe TBI revealed suctioning was associated with both a clinically and statistically significant elevation in ICP from baseline, with a mean ICP rise of 8.6 mm Hg.⁸ As expected, children with higher baseline ICPs showed a more significant ICP response. Despite this ICP rise with suctioning, 68% of children had recovered their baseline ICP within 5 minutes, with a median time of 3 minutes (range: 0–90 minutes).

Children with Congenital Heart Disease

Despite the known risks of suctioning children with congenital heart disease (indicated by many PICUs having detailed guidelines for suctioning in these children), there is a dearth of published literature on this topic. Only one study⁹ has examined the effect of an opiate (fentanyl) on blunting the pulmonary vascular response with suctioning. Reactive pulmonary hypertension (caused most commonly by excessive pulmonary blood flow preoperatively) is a common problem in the cardiac PICU. Endotracheal suctioning is a known noxious trigger in this group of children, albeit one that is necessary. Hickey et al⁹ studied 14 children (mean $\pm$ SD age:

7 ± 2.7 months) after a variety of cardiac surgical procedures in the PICU. Standard practice at this time was to use direct pulmonary artery lines to measure pressures postoperatively. The children were all open suctioned (in a much briefer method than the way used in clinical practice), yet HR and MAP increased moderately, whereas mean pulmonary artery pressure increased significantly in response to suctioning. After this “baseline” suction, the patients were administered 25 µg/kg of fentanyl over 1 to 2 minutes in addition to a muscle relaxant (pancuronium). The same suctioning was repeated after 10 minutes and the results were significantly different, with HR, MAP, and mean pulmonary artery pressure all significantly decreased with fentanyl. The most marked response was in the pulmonary circulation where the pulmonary vascular response was markedly reduced. This study was limited by the lack of reporting of the sedation level and drugs before the baseline suction and the very large fentanyl dose and by combining it with a muscle relaxant.

Endotracheal suctioning, although essential, does cause changes in lung compliance and airway resistance, most of which are fairly transient. It also stimulates the tracheal wall, which may produce further sympathetic nervous system effects and raise intracranial pressure. Suctioning is not an innocuous procedure and certain patient groups are at greater risk.

Infection as a Risk of Endotracheal Suction

Two papers have examined the risk of ventilator-associated pneumonia (VAP) in relation to endotracheal suctioning. Scoble et al¹⁰ studied the impact of reusing a suction catheter for all suctioning episodes within a 24-hour period on the incidence of pneumonia. The control group received standard care, which was a new sterile suction catheter for each suction episode. This randomized controlled trial (RCT) of 486 PICU patients included children ventilated longer than 24 hours and excluded those admitted with a lower respiratory tract infection. The primary outcome measure was pneumonia (defined using World Health Organization criteria). They found no difference in pneumonia between the two groups, but there were significant cost savings in reusing the same suction catheter for 24 hours. A further prospective but nonrandomized study on the use of closed suctioning on the incidence of VAP in 250 PICU patients (median age 3.8 months) was undertaken.¹¹ Open and closed suction (CS) were applied to the whole PICU in alternate months. VAP was defined using the Clinical Pulmonary Infection Score and results confirmed using the Centers for Disease Control and Prevention criteria. The overall VAP rate was 45.1 infections per 1,000 ventilator days. Eighty-three patients received CS and 180 open suctioning during their PICU admission, resulting in no significant difference in the VAP rate between groups (20.5 vs. 23.3%). Patients developing VAP stayed significantly longer in the PICU than patients who did not develop VAP ($p < 0.001$). These studies indicate that reusing suction catheters (either in a closed circuit system or otherwise) does not increase the risk of VAP; thus, there is no evidence for using a new suction catheter for each suction pass.

Indications/Assessment for Endotracheal Suction in PICU Patients

Five studies have examined PICU nurses' clinical judgment and determining the need for endotracheal suction. A qualitative study¹² found three themes: cue recognition, weighing the evidence, and skilled performance that were interwoven when nurses considered endotracheal suction. Others¹³ found the five top criteria for determining if suction is required were suspected obstruction of the ETT by secretions, visible or audible secretions, decreased oxygen saturation/cyanosis, suspected aspiration, and dyspnea or signs of respiratory distress. From this, they developed and validated an endotracheal suction assessment tool that PICU nurses could use to determine suctioning needs. A further qualitative study¹⁴ found four main reasons why nurses performed suction: the child coughing, a routine procedure, a change in monitored signs, and a change in the child's behavior. Eighty-one percent of suctioning episodes were performed in response to an alteration in the child's condition, indicating that nurses assessed the need for suctioning, rather than suctioning routinely. Similar indications for suctioning were noted in an Australian study of PICU nurses,¹⁵ with the following common indications for suctioning: arterial desaturation, hemodynamic changes, change in skin color, and blood gas deterioration. A survey undertaken in 92 US PICUs in the early 1990s¹⁶ revealed several variables that nurses considered in their decision to suction. In order of importance these were the amount of secretions, breath sounds, oxygen saturation, secretion consistency, tolerance of suctioning, response to suctioning, diagnosis, the arterial or capillary blood gas, and the end tidal partial pressure of carbon dioxide level or other transcutaneously measured carbon dioxide or oxygen level, along with the child's age. Assessment of the child and their need for endotracheal suction is clearly an important nursing concern, although there remains a lack of conclusive evidence about this assessment process.

Evidence in Endotracheal Suctioning Techniques

The Use of Closed Suction Systems

CS refers to any method in which suctioning is performed without disconnecting the ventilator. It may be achieved either by using specifically designed inline catheters or through an adaptor placed in the ventilator circuit. A systematic review of CS in neonates included four randomized crossover trials, with a combined total of 252 infants.¹⁷ Outcomes varied across the included studies, but meta-analysis found that CS resulted in less HR variability, slightly less bradycardia, and fewer hypoxic episodes. The authors concluded that the strength of evidence was insufficient to recommend routine use of CS. All studies included infants between 24- and 42-week gestation, limiting the generalizability to the PICU context. However, one of the included studies¹⁸ reported subgroup analysis by weight; in infants > 2,000 g ($n = 64$) no differences were found between open suction (OS) and CS in any of the reported outcomes. Similarly, in a study of predominantly (31/39) term neonates, both OS and CS produced transient falls in SpO₂ (peripheral

capillary oxygen saturation), with greater decreases in infants requiring higher ventilatory parameters; however, no differences were found between the two systems.¹⁹ In addition to the data included in the systematic review,¹⁷ Hoellering et al²⁰ compared change in lung volume and time taken to recover lung volume, and performed a subgroup analysis by mode of ventilation (synchronized intermittent mandatory ventilation and high frequency oscillatory ventilation [HFOV]). They found lung volume loss was not influenced by suction method in either ventilation mode. Time to recover lung volume was significantly longer following OS than CS in infants receiving HFOV, with no difference in infants receiving synchronized intermittent mandatory ventilation. The authors speculated that the difference in the HFOV group could be at least partially attributed to the higher level of sedation in this group, with the longest recovery times seen in infants receiving neuromuscular blockade.

Two studies have compared the short-term effects of OS and CS in children beyond the neonatal period. In a randomized crossover trial in 14 children, Choong et al²¹ found lung volume loss (both in absolute terms and as a percentage of tidal volume) was greater with OS than with CS. These differences were statistically significant only in children with noncompliant lungs. The sample size was small and the sample heterogeneous in terms of age and diagnosis; moreover, all patients were muscle relaxed, which is no longer common practice in most PICUs. In a nonrandomized study of 6,691 suction events in 258 children, Evans et al²² found that OS was more likely to be associated with falls in oxygenation and increases in MAP and HR, each defined as a change of at least 20%. CS was performed more frequently than OS (7.2 vs. 6.0 times per day) and was associated with less nursing time. Similar numbers of adverse events were reported with both systems but there was a difference in the type of events. Dislodged ETT occurred more often with OS ($n = 3$) than with CS ($n = 1$), while all episodes of ETT blockage ($n = 4$) occurred with CS. Data were recorded by the bedside nurse rather than a dedicated researcher, increasing the potential for inaccuracy and bias, and no patient demographics were reported.

In an animal study, rabbits with lavage-induced lung injury (a model similar to pediatric acute respiratory distress syndrome [ARDS]) were suctioned repeatedly over a 6-hour period using either CS or OS.²³ Rabbits subjected to OS demonstrated gradual and time-dependent decrease in oxygenation, presumably due to repeated derecruitment, while oxygenation was unaffected in the CS group. Lung injury at the end of the experiment, assessed by histological examination and measurement of inflammatory cytokines, did not differ between the two suction groups and was similar to a control group with ARDS that did not receive suction.

The effectiveness of OS and CS in removing secretions has been investigated in only one study. In an animal model (adult rabbits intubated with a 3.5-mm ETT), Copnell et al²⁴ compared the recovery of simulated thin and thick mucus by OS and CS in three conditions: the normal lung during conventional ventilation (TCPLV); saline-lavaged lungs during TCPLV; and saline-lavaged lungs during HFOV. They found

that significantly lower amounts of both materials were recovered by CS in both lung injury scenarios, with no significant difference in the normal lung. The similarity of the simulated secretions to human respiratory mucus was not reported and there were several differences between the experimental model and the clinical scenario. However, this difference may explain the need for more frequent suction and incidence, albeit small, of blocked ETTs with CS, observed by Evans et al.²²

In summary, there is some evidence that CS results in greater physiological stability in neonates and children than OS. CS may be less effective in removing secretions, at least in some circumstances. The clinical significance of these findings is unclear, and no studies have examined long-term outcomes.

Catheter Size and Suction Pressure

Bench tests have demonstrated that, at least during OS, negative pressure generated in the trachea²⁵ or within a test lung²⁶ is mainly dependent on the difference in cross-sectional area between the catheter and ETT. This effect was tested using all possible catheter sizes with ETTs between 2.5 and 4.0 mm and negative pressures between 80 and 200 mm Hg,²⁷ and with ETTs between 2.0 and 7.0 mm and negative pressures between 200 and 500 mm Hg,²⁶ although the two studies produced different mathematical models to explain the findings. Similar tests of CS during TCPLV,^{27,28} HFOV,²⁷ and volume guarantee ventilation²⁹ demonstrated more complex relations between ETT size, relative catheter size, and suction pressure. Tidal volume was compromised by the presence of the catheter in the ETT, and negative intratracheal pressures were considerably higher than with OS when larger catheters and/or higher suction pressures were used.²⁷⁻²⁹ During volume guarantee ventilation, the potential for extremely high airway pressures to be delivered following suction was identified.²⁹ Studies of CS only used equipment suitable for neonates and small infants, and the effects with larger equipment are unknown. Moreover, the studies excluded the effect of mucus in the airways.

The effects of various combinations of catheter size and suction pressure on global and regional lung volume changes were examined in an animal model (neonatal piglets intubated with a 4.0-mm ETT).^{5,30} During OS, neither catheter size nor suction pressure influenced volume loss or recovery. During CS, volume loss increased with increasing catheter size and negative pressure; with an 8 Fr catheter and negative pressure of ≥ 140 mm Hg, volume loss was equivalent with OS and CS, during both TCPLV and HFOV. The study was limited to a single model of lung pathology and the animals were muscle relaxed, which is not routine practice in most PICUs. Suctioning was limited to one pass of the catheter and the presence or absence of secretions was not addressed. Similarly, a study of CS in a rabbit model during jet ventilation found catheter size to have the greatest influence on loss of lung volume and fall in intratracheal pressure.³¹ Limitations of the study were similar to previous experiments.^{5,30}

Few clinical studies have investigated catheter size and suction pressure. Singh et al³² found no difference in changes

in HR, MAP, respiratory rate, SpO₂, or ICP when using catheters with diameters 40, 70, and 90% of that of the ETT and negative pressures of 80, 100, and 120 mm Hg during OS. Conversely, Morrow et al⁴ reported that smaller differences between ETT and suction catheter cross-sectional area were associated with greater decreases in dynamic compliance following OS. This study used a single negative pressure of ~360 mm Hg. Boothroyd et al³³ found that limiting suction pressure to 120 mm Hg resulted in a decrease in right upper lobe (RUL) collapse; however, this variable was not studied in isolation, the pressure applied in the comparison group was unknown, and catheter size relative to ETT size was not stated. No similar studies have been undertaken during CS.

In summary, bench and animal experiments indicate that catheter size and suction pressure are not independent but should be considered in relation to each other. The potential for high negative tracheal pressures during CS is of particular concern. There is little clinical evidence to support appropriate combinations to minimize adverse effects. The most effective combination to remove secretions is unknown.

Preoxygenation before Suctioning

Administration of 100% oxygen prior to suctioning has been investigated in PICU patients in two studies. Feaster et al³⁴ studied seven children between the ages of 8 and 27 months requiring long-term ventilation, mainly for chronic lung disease, all of whom routinely received chest physiotherapy prior to suction. Hyperoxygenation was not studied in isolation, but in combination with either hyperinflation or both hyperinflation and hyperventilation; these techniques were compared with hyperinflation alone and hyperinflation and hyperventilation. There was no control (e.g., suction with no intervention). All techniques prevented clinically significant falls in SpO₂ during the procedure. Because of the study design, the effect of hyperoxygenation is difficult to evaluate.

Kerem et al³⁵ examined the effect of 100% oxygen administered from 1 minute prior to suction on arterial blood gases in 25 children aged between 1 day and 10 years, and compared it with the effect of no supplementary oxygen. Overall, preoxygenation resulted in a 78% increase in partial pressure of oxygen in arterial blood (PaO₂) before suction; immediately following suctioning, PaO₂ decreased but was still higher than baseline, with a return to baseline at 5 minutes postsuction. With no preoxygenation, PaO₂ fell by 20% immediately following the procedure and had returned to baseline within 5 minutes. Only in those children whose oxygenation was low or borderline presuctioning became hypoxemic during the procedure. No other subanalyses were performed. The study was conducted in 1990; it was notable that the mean baseline PaO₂ was 117 to 120 mm Hg, higher than is usual with modern ventilation strategies.

In a more recent randomized crossover trial in 15 neonates (gestational age $\geq$ 37 weeks in 11/15, age range: 1–24 days), three techniques to prevent hypoxemia (hyperoxygenation with 10% above baseline, hyperventilation with 50% increase in rate of inflations, and both) were compared with no maneuver.³⁶ All three techniques resulted in an initial increase in SpO₂, which remained above baseline during

suctioning only with hyperoxygenation alone. Similarly, this was the only technique in which SpO₂ was significantly higher than the control condition at 0, 1, and 5 minutes postsuctioning. With all three techniques, SpO₂ was significantly higher than baseline at 5 minutes postsuctioning. Mean SpO₂ at baseline was 83.7%, presumably indicating suboptimal ventilation due to the need for suctioning. With hyperoxia, the final mean SpO₂ was ~93%; whether this was desirable in all patients studied was not discussed but seems unlikely. The suctioning technique included chest physiotherapy, instillation of saline, and deep suctioning, none of which are recommended as routine practice.^{1,37}

All the above studies used OS, and no studies have compared the effects of preoxygenation with OS and CS. It remains to be determined whether preoxygenation is required when CS is used. Guidelines^{1,37} recommend preoxygenation with 100% oxygen for most, if not all, pediatric patients. This would seem to conflict with lung protective ventilation strategies, which aim to minimize FiO₂; investigations to determine whether hypoxemia can be prevented by using lower concentrations of oxygen, as recommended in neonates,^{1,37} are warranted.

Depth of Suction Catheter Insertion

Depth of suctioning does not appear to have been studied directly in pediatric patients. Shallow suctioning is defined as passing the catheter to the tip of the ETT, and deep suctioning as passing the catheter beyond the tip, usually until resistance is felt.³⁸ A systematic review of deep and shallow suctioning in neonates and infants³⁸ included only one study, a randomized crossover trial in 22 infants of varying gestational age. Preterm and term infants were not analyzed separately. There were no differences in the primary outcomes of HR or oxygen saturations between the two methods. However, cytological examination of the aspirated mucus indicated damage to the tracheal mucosa.³⁹ The applied suctioning pressure was not stated. This finding is supported by evidence from a study performed in rabbits, in which deep suctioning was associated with significantly more tissue necrosis and inflammation than shallow suction.⁴⁰ Moreover, deep suctioning did not recover more mucus than shallow suctioning, a finding also noted by Ahn and Hwang.³⁹

Only one study in children has evaluated the effects of depth of suctioning. In an audit, Boothroyd et al³³ examined the incidence of RUL collapse in a pediatric cardiac intensive care unit over two 3-month periods; in the first, suctioning was performed with no regulation of suction depth or applied pressure, and in the second, shallow suctioning was performed with negative pressure limited to 120 mm Hg. They found a significant decrease in RUL collapse from 24 to 7% during the second period. These findings are difficult to interpret as two interventions were introduced simultaneously and neither depth of suctioning nor suctioning pressure was documented during the first audit period.

From the limited evidence available, it appears that deep suctioning has no advantage over shallow and carries the risk of mucosal damage and possibly other morbidities. There is no evidence to support this practice.

Table 1 Recommendations for endotracheal suctioning in pediatric intensive care unit

	Evidence statement	Recommendation
Risk of endotracheal suction	Endotracheal suctioning is not an innocuous procedure and in certain high-risk pediatric intensive care patient groups it is even more risky.	Pediatric intensive care nurses should carefully assess and determine the need for endotracheal suction and take precautions to minimize the risk.
Reusing suction catheters	Reusing suction catheters (either in a closed circuit system or otherwise) does not increase the risk of ventilator-associated pneumonia.	There is no evidence for using a new suction catheter for each suction pass.
Assessment	Assessment of the children and their need for endotracheal suction is important.	There is no evidence to support protocolized assessment.
Closed suction	Closed suction may result in greater physiological stability in neonates and children than open suction. However, closed suction may be less effective in removing secretions, at least in some circumstances.	The use of closed circuit suction must be assessed on an individual-patient basis in relation to ventilation mode and secretion volume and tenacity.
Catheter size and suction pressure	Catheter size and suction pressure are not independent but should be considered in relation to each other. The potential for high negative tracheal pressures during closed suction is of particular concern.	There is little clinical evidence to support appropriate combinations for each endotracheal tube size to minimize adverse effects. The most effective combination to remove secretions is unknown. Smaller catheters relative to endotracheal tube can be used with higher suction pressures. Particular care should be taken in selecting both during closed suction. Staff should be aware of the potential for high negative pressures to be generated in some situations.
Preoxygenation	Endotracheal suctioning produces a transient fall in oxygenation, with hypoxemia reported mainly in patients with lung pathology.	Guidelines recommend preoxygenation for most pediatric intensive care patients, but the level of preoxygenation required is not known. There is no evidence for or against its use during closed suction. It is suggested that the amount of oxygen required to prevent hypoxemia be assessed on a case-by-case basis. In certain high-risk groups (congenital heart disease with unrestricted pulmonary blood flow), preoxygenation is not recommended and an oxygen mixer must be used to accurately control the amount of oxygen delivered.
Depth of suctioning	Deep suctioning has no advantage over shallow and carries the risk of mucosal damage and possibly other morbidities.	There is no evidence to support the practice of deep (to carina) suctioning; shallow suction to or just beyond the tip of endotracheal tube is recommended.
Saline instillation during suctioning	There is some evidence that saline instillation causes transient adverse effects. There are conflicting findings concerning its potential benefits.	Instillation of saline cannot be recommended as routine practice. It may be of benefit in certain situations. Decisions regarding its use should be based on individual patient assessment but should be made with caution.
Recruitment maneuvers	Recruitment maneuvers after suctioning show conflicting results regarding efficacy and some safety issues have been raised.	Recruitment maneuvers after suctioning cannot be recommended as routine practice.

Saline Instillation

Instillation of saline into the ETT prior to suctioning to assist in secretion recovery has been little investigated among PICU patients. In an RCT of 24 children aged 10 weeks to 14 years, and including 104 suctioning episodes, saline instillation was associated with lower SpO₂ at 1 and 2 minutes postsuctioning than when saline was not used (5.7 and 4.8% change from baseline vs 1.5 and 1.0%).⁴¹ Actual SaO₂ values were not reported, making the clinical significance difficult to evaluate. There were no instances of ETT blockage or pneumonia in either group. No power calculation was provided. A randomized crossover trial of nine term infants with meconium aspiration syndrome⁴² found airway resistance fell significantly following suctioning with saline and was unchanged with no saline. There was no difference in change in pulmonary compliance or SpO₂ between the interventions. In a similar study of 25 neonates with respiratory distress,⁴³ no differences were found in arterial blood gases, HR, or MAP between suctioning performed with and without saline. The number of term infants in the sample was not stated and these infants were not analyzed separately; hence, caution is required in extrapolating these findings to the PICU context.

The Effect of Recruitment Maneuvers after Suctioning in PICU Patients

Only two papers have studied recruitment maneuver (RM) after suctioning in PICU patients. Duff et al⁴⁴ studied the safety and efficacy of sustained inflations (SIs) as a lung RM in 32 PICU children with mixed pathology in a prospective observational study. An SI was defined as 30 to 40 cmH₂O for 15 to 20 seconds, achieved by switching the ventilator to continuous positive airway pressure and setting the positive end-expiratory pressure at the desired level (normal lungs 30–35 cmH₂O, ARDS 40–45 cmH₂O) for 15 to 20 seconds. This was performed in several situations: after suctioning, with hypoxemia, following ventilator disconnection, and routinely every 12 hours. They examined physiologic parameters for 6 hours after the SI. Ninety-three RMs were performed in 32 children (median age 16 months). A total of 7.5% of RMs were stopped due to patient agitation and 2.2% for bradycardia. They found no statistically significant changes from pre-RM to post-RM in HR, systolic BP, or SaO₂. In three children with elevated ICP, this RM was associated with a spike in ICP. They found a significant sustained decrease in oxygen requirements (by 6.1%) lasting up to 6 hours post-RM; thus, they concluded that RMs are safe and may improve oxygen requirements.

A further RCT, however, showed inconclusive results. This study evaluated the impact of RM after endotracheal suctioning⁴⁵ in 48 PICU children with mixed lung pathology. Children underwent a standardized suctioning procedure and then, 5 minutes later, the intervention group underwent a standardized RM. Suctioning involved a single suction pass and preoxygenation at 100%. The RM comprised a single sustained manual inflation breath at a pressure of 30 cmH₂O applied for 30 seconds. Outcome measures were respiratory mechanics (lung compliance, tidal volume, respiratory rate, and airway resistance) and oxygenation (SpO₂) before and up to 25 minutes after the procedure. They found no difference in any of these parameters

after the procedure. In the RM group, there were reduced machine-delivered tidal volumes, but increased spontaneous patient tidal volumes with an increase in respiratory rate; however, these effects disappeared after 25 minutes. With conflicting results regarding the efficacy of RMs and some safety issues raised, this practice cannot be recommended.

Recommendations for Future Research

Practice recommendations for endotracheal suctioning are presented in ►Table 1. This review demonstrates the overall paucity of robust pediatric evidence related to suctioning practices. There are few RCTs and no systematic reviews except in preterm neonates and there is large heterogeneity in the published studies. Much of the research is dated and does not reflect contemporary practices in managing critically ill children, in either suctioning or ventilation techniques. Endotracheal suction should support the ventilator strategy; advances in ventilation require reconsideration of suction practice. Research into the interaction between suction (particularly closed techniques) and newer ventilation modes is rare and much of the research has focused on the short-term effects of suction, and the clinical significance of these findings is unclear. There is a need for examination of longer-term outcomes such as duration of respiratory support and length of intensive care unit stay, and an understanding of the different responses to suction is required.

Published guidelines on the topic are, in general, suggestions rather than recommendations, due to this low-level evidence. In addition, there is an almost complete lack of evidence in relation to specific conditions such as congenital heart disease. It is evident that almost nothing is known about the effectiveness of various suction techniques. The removal of secretions (to prevent ETT occlusion) is the sole reason for performing suctioning; techniques that do not achieve this will expose children to potential adverse effects of suctioning without providing any benefit. Further larger-scale (international) surveys (or point prevalence studies) of PICU nurses' practice of endotracheal suctioning would also be useful as understanding the range of practices in use would help researchers make decisions about study protocols.

In conclusion, although endotracheal suctioning of intubated children is essential, it is not an innocuous procedure. This paper has provided an up-to-date review of research related to endotracheal suctioning that involves or relates to children in intensive care. It has concluded with recommendations for practice and has identified areas for future research.

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