0031-3998/09/6604-0364
PEDIATRIC RESEARCH

Vol. 66, No. 4, 2009
Printed in U.S.A.

COMMENTARY

Endotracheal Suctioning Is Basic Intensive Care or Is it?

Commentary on article by Copnell *et al.* on page 405

ANDREW C. ARGENT

Division of Paediatric Critical Care, Red Cross War Memorial Children's Hospital, University of Cape Town, Rondebosch, Cape Town 7700, South Africa

Although the need for intensive care has often been defined by the need for ventilation, and there are literally thousands of publications on techniques, principles, complications, and challenges of ventilation, there is a surprising lack of evidence for best practice regarding a fundamental technique in ventilation: suctioning of the airway. Since tracheostomy or endotracheal intubation was first undertaken, potential obstruction of the endotracheal tube by mucus has been a consistent and life-threatening problem. That has been particularly true for infants and children, especially those with increased respiratory secretions. The obvious (not always so easy) solution is adequate humidification and suctioning. Thus, endotracheal suctioning is probably the most common procedure in pediatric and neonatal intensive care practice.

The ideal suctioning technique would be pain- and discomfort-free, safe (with no adverse events such as loss of lung volume, desaturation, cardiovascular changes, CNS changes, damage to the respiratory system at any level, introduction of infection, *etc*.), and effective (removing all excessive secretions, keeping the endotracheal tube clear and unobstructed).

The reality is that suctioning has been associated with a plethora of adverse events and unpleasant side effects. In preterm infants, it has been associated with changes in cerebral oxygenation (1,2) and pressures (3) and hemodynamics (2–4); in infants, with atelectasis (5), transient bacteremia (6), hypoxia, and cardiovascular changes (7,8); and in children with hypoxia (8) and upper lobe atelectasis (9). For obvious reasons, we do not have the patient's perspective on endotracheal suctioning in infancy. However, in adult studies endotracheal suctioning is clearly remembered as unpleasant and in a recent study, pain on endotracheal suctioning was rated as moderate to severe by more than half the patients (10).

Although detailed recommendations for suctioning technique are available in most pediatric intensive care textbooks, the underlying evidence for the recommendations is often limited and is based on adult data. Although preoxygenation has been widely recommended as a means of decreasing complications after endotracheal suctioning, recent reviews concluded that there was not adequate evidence to fully support the practice in preterm infants (11,12). Similarly there was inadequate evidence to support the practice of nondisconnection of the ventilator during suctioning (13). Recently, a reviewer was unable to find any evidence to address the question of whether endotracheal suctioning in neonates should be limited to keeping the suction catheter within the endotracheal tube or whether it should be extended into the trachea beyond (14). An adult study showed that minimally invasive suctioning (limited to endotracheal tube) was associated with fewer adverse events, no deleterious effects (15), and less subsequent recall of endotracheal suctioning (16). Within the published pediatric literature, there is a wide range of techniques reported (Table 1).

In 1991, Singh *et al.* (17) were among the first to examine detailed techniques in pediatric suctioning (Table 1). Since then a number of studies have focused on the process of endotracheal suctioning. Initial studies considered the theoretical aspects of flow within the endotracheal tube during suctioning (18) and moved on to data obtained with a simple model. Those data were expanded with some studies considering lung mechanics after endotracheal suctioning (19,20). Some elegant theoretical (20,21) and practical studies followed, which highlighted the complexity of flows within suction catheters and endotracheal tubes during endotracheal suction.

The effects of endotracheal suctioning probably depend on many issues including underlying lung pathology, patient sedation and use of paralysis, the details of the suctioning technique, particular ventilatory techniques such as pressure control or volume control modes (22), the use of

Received July 15, 2009; accepted July 17, 2009.
Correspondence: Andrew C. Argent, M.B., B.Ch.(Wits), M.Med.Paeds.(Wits), D.C.H.(SA), F.C.Paeds.(SA), F.R.C.P.C.H.(UK), Pediatric Intensive Care Unit, Red Cross War Memorial Children's Hospital, and School of Child and Adolescent Health, University of Cape Town, Rondebosch, Cape Town 7700, South Africa; e-mail: andrew.argent@uct.ac.za

Table 1. *Some recent publications on endotracheal suctioning in infants and children*

Patient group	Suction pressure	Catheter sizes	Suction technique	Outcome	Reference
17 ventilated infants (age 6.5 + 5 mo)	80,100, and 120 mm Hg	Ratio of outer diameter of suction catheter to inner diameter of endotracheal tube of 0.4, 0.7, and 0.9	Not fully reported	Significant changes in HR, bp, saturation and ICP with all systems. Ratio of 0.7 seemed most effective	17
200 neonates of varying size studied within the first 10 d of life	Not recorded	Not recorded	Instilling 0.5 mL normal saline into the ETT; passing a sterile suction catheter to the end of the ETT (and applying continuous suction as the catheter was withdrawn over 10–15 s. 2 passes of the technique	Infants took longer to return to baseline after open suctioning	24
14 patients aged 6 d to 13 y	100 mm Hg for open and 120 mm Hg for closed suction	8F for endotracheal tube sizes 3.5–4.0 mm and 10F for endotracheal tube sizes 4.5–6.0 mm	Up to 3 passes of 10 s each	Consistently higher losses of volume with open suctioning technique	26
15 extreme low-birthweight infants (range 470–975 g) at mean age of 139 d	Suction pressure was maintained at 100 mm Hg	Not reported	Instillation of 0.2 mL 0.9% saline, followed by 2 passages of the suction catheter to 0.5 cm beyond the tip of the endotracheal tube. After insertion catheter, suction was applied for 1 s before withdrawal	Closed system associated with fewer and less severe episodes of desaturation than open system	25
54 children (median age, 3.3 mo) ventilated with size 4 or less ETT	−360 mm Hg	Variable depending on ETT size	1 pass (open technique) with catheter in ETT for about 10 seconds, but shorter duration suction	Significant drop in dynamic compliance after suctioning	36
30 infants (10 (median weight 3.38 kg and age 3 d) on HFOV and 20 (median weight 1.93 kg and age 18.5 d) on conventional ventilation	6 s at −19 kPa	6F regardless of ETT size	2 passes of 6 s each at 1-min interval	No difference of open *vs* closed on conventional ventilation, but tend to increased drop in lung volume with open on HFOV	27

HR, heart rate; ICP, intracranial pressure; ETT, endotracheal tube; HFOV, high frequency oscillatory ventilation.

PEEP (23), and potentially whether recruitment maneuvers are used after the procedure.

A number of studies have focused on the issue of whether "open" or "closed" systems make a significant difference (24–26). Hoellering *et al.* (27) have recently reported on their studies on endotracheal suctioning in 20 infants [mean gestational age 34.5 wk (24–40 wk), chronological age 18.5 d (3–61 d), and weight 1.93 kg (0.57–5.68 kg) kg] on conventional ventilation. There was no difference in the drop in lung volume (as measured by respiratory impedance tomography) after open or closed suctioning. By contrast, there was a trend toward a drop in lung volume after open suctioning for a group of 10 infants [mean gestational age 40 wk (23–42 wk), chronological age 3 d (1–38 d), and weight 3.28 kg (0.83–3.70 kg)], who were on high-frequency ventilation.

In this edition of the journal, Copnell *et al.* (28) have presented data on "the effect of suction method (open, closed in-line and closed with a side-port adaptor), catheter size and suction pressure on lung volume changes during endotracheal suction" during both conventional and high-frequency oscillatory ventilation. They provided a very carefully standardized model of animals with lung injury analogous to surfactant deficiency (newborn piglets after multiple saline lavage), standardized the ventilatory approach to these animals in line with current recommendations for the ventilation of infants (children and adults) with ARDS, standardized the lung volume of the subjects at all test points, and applied a standardized suction technique with a single pass of the suction catheter to the end of the ETT and 6 s of applied suction (at different pressures). In this study, closed systems did seem to be advantageous with regard to maintenance of lung volume, but only in certain circumstances, and even then not at a clinically significant level.

How do these findings relate to current practice in intensive care? First, the specific condition that has been modeled is analogous to hyaline membrane disease and ARDS in older infants and children. In pediatric practice, ARDS is a relatively uncommon reason for ventilation, and much more work will be needed to optimize suctioning in patients with more common conditions such as bronchiolitis and viral or bacterial bronchopneumonia. In a population of patients with variable pathology Choong *et al.* (26) demonstrated an increased loss of lung volume in patients with "noncompliant lungs" (compliance <0.8 mL cm H_2O^{-1} kg^{-1} and fraction of inspired oxygen requirements ≥ 0.4).

The issue of preoxygenation and preparation for suctioning needs to be addressed (11,12). In this particular study, animals were maintained on fraction of inspired oxygen of 1.0 throughout, and the animals were paralyzed and sedated (unlike current practice in most neonatal and pediatric intensive care units).

In both this article (28) and previous studies from the same group (21,29), it was notable that, when using the two smaller catheters (6 and 7FG) at the highest pressure, volume loss was less than or similar to that generated by an 8-FG catheter at the lowest pressure. Thus, recommendations for suctioning need to address both catheter size and suctioning pressure. Furthermore, there was a wide variation in changes in lung function measurements with suctioning—a feature of much the pediatric work related to suctioning and chest physiotherapy techniques (30,31)—despite the standardization of the model.

This article has not addressed the issue of whether there may be regional changes in lung volume (with or without overall changes in lung volume). Lindgren *et al.* (32) in an animal model of acute lung injury (saline lavage) demonstrated that the lung volume loss was predominantly in dorsal regions of the lung (and not from the overall lung), with almost complete deaeration of these areas during open suctioning. They applied suctioning for 10 s with vacuum level -20 kPa (~ -150 mm Hg, -200 cm H_2O) and a 14-F catheter.

The article was not directed at the question of what pattern or method of suctioning is most effective at removing secretions (as pointed out by the authors in the Discussion). In a study of 18 adult patients with acute lung injury (33), it was noticeable that open suctioning removed significantly more secretions than closed suctioning (despite worse desaturation associated with open suctioning). Similarly, more secretions were removed with a suction pressure of -400 cm H_2O than with -200 cm H_2O (32). In previous animal studies (20,23), open suction techniques removed more secretions than closed systems.

Clearly, there is much work to be done to understand the influence of different suctioning systems, different methods and techniques of suctioning, the underlying respiratory pathophysiology of the child, the best possible ways of timing the need for suctioning, and the best techniques for removal of troublesome secretions.

As we learn more about appropriate suctioning techniques, it is probably as important that we address ways of implementing this research at the clinical level. Recently, Kelleher and Andrews (34) studied the practice of open endotracheal suction in two adult intensive care units and found substantial variation in practice and poor adherence to best practice suctioning recommendations. They reported significant discrepancies in practices regarding respiratory assessment techniques, hyperoxygenation and infection control practices, patient reassurance, and the level of negative pressure used to clear secretions. Encouragingly, Day *et al.* (35) demonstrated improvement in both knowledge and practice in a group of nurses who were provided with focused teaching on endotracheal suction techniques.

REFERENCES

1. Kohlhauser C, Bernert G, Hermon M, Popow C, Seidl R, Pollak A 2000 Effects of endotracheal suctioning in high-frequency oscillatory and conventionally ventilated low birth weight neonates on cerebral hemodynamics observed by near infrared spectroscopy (NIRS). Pediatr Pulmonol 29:270–275
2. Shah AR, Kurth CD, Gwiazdowski SG, Chance B, Delivoria-Papadopoulos M 1992 Fluctuations in cerebral oxygenation and blood volume during endotracheal suctioning in premature infants. J Pediatr 120:769–774
3. Durand M, Sangha B, Cabal LA, Hoppenbrouwers T, Hodgman JE 1989 Cardiopulmonary and intracranial pressure changes related to endotracheal suctioning in preterm infants. Crit Care Med 17:506–510
4. Fanconi S, Duc G 1987 Intratracheal suctioning in sick preterm infants: prevention of intracranial hypertension and cerebral hypoperfusion by muscle paralysis. Pediatrics 79:538–543
5. Brandstater B, Muallem M 1969 Atelectasis following tracheal suction in infants. Anesthesiology 31:468–473
6. Storm W 1980 Transient bacteremia following endotracheal suctioning in ventilated newborns. Pediatrics 65:487–490
7. Simbruner G, Coradello H, Fodor M, Havelec L, Lubec G, Pollak A 1981 Effect of tracheal suction on oxygenation, circulation, and lung mechanics in newborn infants. Arch Dis Child 56:326–330
8. Kerem E, Yatsiv I, Goitein KJ 1990 Effect of endotracheal suctioning on arterial blood gases in children. Intensive Care Med 16:95–99
9. Boothroyd AE, Murthy BV, Darbyshire A, Petros AJ 1996 Endotracheal suctioning causes right upper lobe collapse in intubated children. Acta Paediatr 85:1422–1425
10. Arroyo-Novoa CM, Figueroa-Ramos MI, Puntillo KA, Stanik-Hutt J, Thompson CL, White C, Wild LR 2008 Pain related to tracheal suctioning in awake acutely and critically ill adults: a descriptive study. Intensive Crit Care Nurs 24:20–27
11. Pritchard M, Flenady V, Woodgate P 2001 Preoxygenation for tracheal suctioning in intubated, ventilated newborn infants. Cochrane Database Syst Rev 3:CD000427
12. Pritchard MA, Flenady V, Woodgate P 2003 Systematic review of the role of pre-oxygenation for tracheal suctioning in ventilated newborn infants. J Paediatr Child Health 39:163–165
13. Woodgate PG, Flenady V 2001 Tracheal suctioning without disconnection in intubated ventilated neonates. Cochrane Database Syst Rev 2:CD003065
14. Spence K, Gillies D, Waterworth L 2003 Deep versus shallow suction of endotracheal tubes in ventilated neonates and young infants. Cochrane Database Syst Rev 3:CD003309
15. Van de Leur JP, Zwaveling JH, Loef BG, Van der Schans CP 2003 Endotracheal suctioning versus minimally invasive airway suctioning in intubated patients: a prospective randomised controlled trial. Intensive Care Med 29:426–432
16. Van de Leur JP, Zwaveling JH, Loef BG, Van der Schans CP 2003 Patient recollection of airway suctioning in the ICU: routine versus a minimally invasive procedure. Intensive Care Med 29:433–436
17. Singh NC, Kissoon N, Frewen T, Tiffin N 1991 Physiological responses to endotracheal and oral suctioning in paediatric patients: the influence of endotracheal tube sizes and suction pressures. Clin Intensive Care 2:345–350
18. Morrow BM, Futter MJ, Argent AC 2004 Endotracheal suctioning: from principles to practice. Intensive Care Med 30:1167–1174
19. Morrow B, Futter M, Argent A 2007 A recruitment manoeuvre performed after endotracheal suction does not increase dynamic compliance in ventilated paediatric patients: a randomised controlled trial. Aust J Physiother 53:163–169
20. Copnell B, Tingay DG, Kiraly NJ, Sourial M, Gordon MJ, Mills JF, Morley CJ, Dargaville PA 2007 A comparison of the effectiveness of open and closed endotracheal suction. Intensive Care Med 33:1655–1662
21. Kiraly NJ, Tingay DG, Mills JF, Morley CJ, Dargaville PA, Copnell B 2009 The Effects of closed endotracheal suction on ventilation during conventional and high frequency oscillatory ventilation. Pediatr Res 66:XXX–XXX
22. Almgren B, Wickerts CJ, Hogman M 2004 Post-suction recruitment manoeuvre restores lung function in healthy, anaesthetized pigs. Anaesth Intensive Care 32:339–345
23. Lindgren S, Almgren B, Hogman M, Lethvall S, Houltz E, Lundin S, Stenqvist O 2004 Effectiveness and side effects of closed and open suctioning: an experimental evaluation. Intensive Care Med 30:1630–1637
24. Kalyn A, Blatz S, Sandra F, Paes B, Bautista C 2003 Closed suctioning of intubated neonates maintains better physiologic stability: a randomized trial. J Perinatol 23:218–222

25. Tan AM, Gomez JM, Mathews J, Williams M, Paratz J, Rajadurai VS 2005 Closed versus partially ventilated endotracheal suction in extremely preterm neonates: physiologic consequences. Intensive Crit Care Nurs 21:234–242
26. Choong K, Chatrkaw P, Frndova H, Cox PN 2003 Comparison of loss in lung volume with open versus in-line catheter endotracheal suctioning. Pediatr Crit Care Med 4:69–73
27. Hoellering AB, Copnell B, Dargaville PA, Mills JF, Morley CJ, Tingay DG 2008 Lung volume and cardiorespiratory changes during open and closed endotracheal suction in ventilated newborn infants. Arch Dis Child Fetal Neonatal Ed 93:F436–F441
28. Copnell B, Dargaville PA, Ryan EM, Kiraly NJ, Chin LO, Mills JF, Tingay DG 2009 The effect of suction method, catheter size and suction pressure on lung volume changes during endotracheal suction in piglets. Pediatr Res 66:XXX–XXX
29. Kiraly NJ, Tingay DG, Mills JF, Morley CJ, Copnell B 2008 Negative tracheal pressure during neonatal endotracheal suction. Pediatr Res 64:29–33
30. Main E, Stocks J 2004 The influence of physiotherapy and suction on respiratory deadspace in ventilated children. Intensive Care Med 30:1152–1159
31. Main E, Castle R, Newham D, Stocks J 2004 Respiratory physiotherapy vs. suction: the effects on respiratory function in ventilated infants and children. Intensive Care Med 30:1144–1151
32. Lindgren S, Odenstedt H, Olegard C, Sondergaard S, Lundin S, Stenqvist O 2007 Regional lung derecruitment after endotracheal suction during volume- or pressure-controlled ventilation: a study using electric impedance tomography. Intensive Care Med 33:172–180
33. Lasocki S, Lu Q, Sartorius A, Fouillat D, Remerand F, Rouby JJ 2006 Open and closed-circuit endotracheal suctioning in acute lung injury: efficiency and effects on gas exchange. Anesthesiology 104:39–47
34. Kelleher S, Andrews T 2008 An observational study on the open-system endotracheal suctioning practices of critical care nurses. J Clin Nurs 17:360–369
35. Day T, Wainwright SP, Wilson-Barnett J 2001 An evaluation of a teaching intervention to improve the practice of endotracheal suctioning in intensive care units. J Clin Nurs 10:682–696
36. Morrow B, Futter M, Argent A 2006 Effect of endotracheal suction on lung dynamics in mechanically-ventilated paediatric patients. Aust J Physiother 52:121–126