Intensive Care Med (2019) 45:1632–1634
https://doi.org/10.1007/s00134-019-05777-w

LESS IS MORE IN INTENSIVE CARE

Endotracheal tube management during mechanical ventilation: less is more!

Robert M. Kacmarek[1,2*] and Gianluigi Li Bassi[3,4,5]

Care of the endotracheal tube (ETT) is frequently not the primary focus of ventilatory management of the critically ill, but it does have a major impact on the trajectory of recovery and complications that can extend long after the patient is extubated. Much of the approach to manage the airway is based on long-standing assumptions, not founded on evidence. As with all aspects of caring for the patient on mechanical ventilation (MV), evidenced-based medicine should be the rule. All aspects of airway care should be based on what is most appropriate for the patient.

The ETT is a conduit for the aspiration of contaminated oral secretions [1]. Commercially available ETTs cuffs are larger in size than human trachea internal diameter [2]. As a result, upon inflation, folds form on the cuff surface, because of cuff design or the anatomic structure of the trachea, which transmit higher pressure against the tracheal wall and establish channels through which secretions can move via capillary action [3]. This movement can be minimized by good oral hygiene, removing secretions [4] and maintaining an appropriate cuff inflation pressure [5]. Cuff pressure needs to be maintained at a level that does not cause inhibition of tracheal blood flow, but minimizes the movement of fluid. With the current ETT cuffs, because of their high-volume low-pressure design, it is impossible to prevent this "silent aspiration". Most recent clinical trials have failed to show any benefit, even with the use of the most promising cuffs [6]. Most guidelines suggest a cuff inflation pressure of 20–30 cm H_2O [7] specifically applying the minimum pressure that prevents leak at peak airway pressure. ETTs cuffs should closely fit the tracheal internal diameter [2]. Given that internal tracheal diameter ranges between 20–25 and 15–21 mm in men and women, respectively, the most appropriate cuff diameter, as reported on the ETT containing package, should be used. The application of positive end-expiratory pressure (PEEP), $\geq$ 5 cm H_2O, minimizes fluid movement across the cuff by counterbalancing the hydrostatic pressure above the cuff [8].

The use of ETTs with subglottic suction decreases VAP and are cost effective [9]. However, what is still unclear is how best to remove secretions, through continuous or intermittent suction [10]. Preliminary data indicate tracheal injury with continuous suction [11]. Based on our clinical experience we prefer intermittent suction.

Airway suctioning is a very controversial topic. What suction pressure? How frequent? How deep? What type of catheter? Airway suctioning is another example of where less is more. Artificial airways should never be suctioned at regular intervals, because of the risks of tracheal injury when secretions are not retained within the airways [12]. Airway suction should only occur if auscultation reveals secretions in the larger airway, the peak airway pressures increases, or the airway pressure waveform indicates fluid in the system, i.e., sawtooth pattern.

Suction pressure should be regulated, in adults 120–140 mmHg [13]. Because of the trauma caused by suctioning; desaturation, cardiovascular compromise [14] and mucociliary clearance impairment [15], the suction catheter should only reach at maximum, the carina and care should be exercised to avoid the lateral eye of the catheter from adhering to the tracheal wall, through swift intermittent suction and continuous rotation of the catheter. If deep tracheal suctioning is required, this should be performed under direct observation during bronchoscopy.

Two airway suctioning approaches exist today—open (OSS) and closed airway suctioning (CSS). OSS require the patient be disconnected from MV before suctioning,

*Correspondence: rkacmarek@partners.org
[2] Respiratory Care, Massachusetts General Hospital, Boston, MA, USA
Full author information is available at the end of the article

Table 1 Do's and Don'ts of ETT management during mechanical ventilation

Do's	Don'ts	Comments
Use ETTs comprising cuffs that closely fit human trachea	Use ETTs comprising very large cuffs	Guidelines recommend
Inflate ETT cuff to 20–30 cm H_2O	Overinflate or underinflate ETT cuff	Guidelines recommend
Intermittent gentle suction of subglottic secretions and prompt interruption if resistance upon aspiration is encountered	Continuous aspiration of subglottic secretions	Controversial
Set wall suction at 120–140 mmHg pressure	Use higher suction pressures	Guidelines recommend
Suction only to the level of the carina	Perform deep suction without bronchoscopy guidance	Guidelines recommend
Tracheal suction only when retained secretions are evident	Recurring tracheal suctioning	Controversial
Use single closed suction system	Use single-use open suction systems	Controversial
Optimize humidification of gases	Use minimal humidification	Guidelines recommend
Leave the patient connected to the ventilator throughout the suctioning procedure	Disconnect the patient from the ventilator and perform manual bag ventilation	Controversial
Use saline instillation with obstruction only	Use saline instillation prior to all suctioning	Controversial

ETT endotracheal tube

while CSS are part of the ventilator circuit. Despite manufacturer's recommendations to change these in-line CSS catheters frequently, there is no evidence of patient harm if they are used until malfunctioning, normally allowing for use of a single catheter for over 2 weeks [16]. This also makes intuitive sense, since we do not routinely change the ETT. This of course is a benefit to the patient, since OSS causes substantial pulmonary volume loss, mostly secondary to the ventilator disconnection. In addition, CSS are cost effective. A single-use catheter through a swivel connector also avoids ventilator discontinuance.

Routine instillation of normal saline is highly controversial [17, 18]. One RCT [18] showed that the instillation of isotonic saline, before tracheal suctioning decreases the incidence of microbiological proven VAP. However, our clinical experiences differ from these results. Saline solution hardly emulsifies thick and tenacious secretions and alternative strategies are available for airway obstruction. Furthermore, thick tenacious secretions normally imply inadequate humidification of ventilatory gases and/or a negative fluid balance. Routine instillation of saline has been associated with increased airway pressure, desaturation, asynchrony and cardiovascular compromise. In addition, the volume of fluid instilled is never recovered during the subsequent suctioning attempt, ultimately resulting in an increase in retained secretions.

Manual ventilation before suctioning results in a loss of PEEP, pulmonary collapse and desaturation, especially with high PEEP. This is recovered by manual ventilation with PEEP. But at what cost? It is highly unlikely that a pressure manometer is maintained in-line while ventilating? The clinician has no idea of the level of pressure being applied to the lung. Lung-protective ventilation should be applied to all patients requiring ventilatory support [19]. When pressures have been measured during manual ventilation pressure commonly exceeds 60 cm H_2O, establishing a plateau pressure $\geq$ 50 cm H_2O increasing the likelihood of ventilator-induced lung injury [20]. Most importantly, there is no data to support the use of manual ventilation preceding airway suctioning (Table 1 summary of recommendations).

Airway care is frequently a bedside technique that is taken for granted, utilizing techniques that are not based on evidence with the perception that more is better. More, however, can cause airway injury, ventilator-induced lung injury, desaturation and cardiovascular compromise. This is an area where additional research is needed. Appropriate application of a technique is always more beneficial than the concept of MORE!

Author details
[1] Department of Anesthesiology, Harvard Medical School, Boston, MA, USA. [2] Respiratory Care, Massachusetts General Hospital, Boston, MA, USA. [3] Division of Animal Experimentation, Critical Care Research Group, The Prince Charles Hospital, Chermside, Australia. [4] University of Queensland, Brisbane, Australia. [5] BITRECS Fellow, Institut d'Investigacions Biomèdiques August Pi i Sunyer (IDIBAPS), Barcelona, Spain.

Compliance with ethical standards

Conflicts of interest
Dr. Kacmarek is a consultant for Orange Medical and Medtronic and has received research grants from Orange Medical and Medtronic. Dr. Bassi has no conflicts of interest.

Publisher's Note

Received: 3 July 2019 Accepted: 3 September 2019
Published online: 17 September 2019

References

1. Young PJ, Rollinson M, Downward G, Henderson S (1997) Leakage of fluid past the tracheal tube cuff in a benchtop model. Br J Anaesth 78:557–562
2. Li Bassi G, Ranzani OT, Marti JD et al (2013) An in vitro study to assess determinant features associated with fluid sealing in the design of endotracheal tube cuffs and exerted tracheal pressures. Crit Care Med 41:518–526. https://doi.org/10.1097/CCM.0b013e31826a4804
3. Pitts R, Fisher D, Sulemanji D et al (2010) Variables affecting leakage past endotracheal tube cuffs: a bench study. Intensive Care Med 36:2066–2073. https://doi.org/10.1007/s00134-010-2048-5
4. Caroff DA, Li L, Muscedere J, Klompas M (2016) Subglottic secretion drainage and objective outcomes: a systematic review and meta-analysis. Crit Care Med 44:830–840. https://doi.org/10.1097/CCM.0000000000001414
5. Girard TD, Alhazzani W, Kress JP et al (2016) An official American Thoracic Society/American College of Chest Physicians Clinical Practice Guideline: liberation from mechanical ventilation in critically ill adults. Rehabilitation protocols, ventilator liberation protocols, and cuff leak tests. Am J Respir Crit Care Med 195:120–133. https://doi.org/10.1164/rccm.201610-2075ST
6. Monsel A, Lu Q, Le Corre M et al (2016) Tapered-cuff endotracheal tube does not prevent early postoperative pneumonia compared with spherical-cuff endotracheal tube after major vascular surgery: a randomized controlled trial. Anesthesiology 124:1041–1052. https://doi.org/10.1097/ALN.0000000000001053
7. Klompas M, Branson R, Eichenwald EC et al (2014) Strategies to prevent ventilator-associated pneumonia in acute care hospitals: 2014 update. Infect Control Hosp Epidemiol 35(Suppl 2):S133–S154
8. Lucangelo U, Zin WA, Antonaglia V et al (2008) Effect of positive expiratory pressure and type of tracheal cuff on the incidence of aspiration in mechanically ventilated patients in an intensive care unit. Crit Care Med 36:409–413. https://doi.org/10.1097/01.CCM.0000297888.82492.31
9. Branch-Elliman W, Wright SB, Howell MD (2015) Determining the ideal strategy for ventilator-associated pneumonia prevention. Cost-benefit analysis. Am J Respir Crit Care Med 192:57–63
10. Lacherade JC, De Jonghe B, Guezennec P, Debbat K, Hayon J, Monsel A, Fangio P, Appere de Vecchi C, Ramaut C, Outin H, Bastuji-Garin S (2010) Intermittent subglottic secretion drainage and ventilator-associated pneumonia: a multicenter trial. Am J Respir Crit Care Med 182:910–917
11. Li Bassi G, Luque N, Martí JD et al (2015) Endotracheal tubes for critically ill patients: an In vivo analysis of associated tracheal injury, mucociliary clearance, and sealing effi cacy. Chest 147:1327–1335. https://doi.org/10.1378/chest.14-1438
12. Ntoumenopoulos G, Berry MP, Camporota L, Lam L (2019) Indicators of Airway secretion weight in mechanically ventilated subjects. Respir Care. https://doi.org/10.4187/respcare.06437
13. AARC (2010) AARC clinical practice guidelines. Endotracheal suctioning of mechanically ventilated patients with artificial airways 2010. Respir Care 55:758–764
14. Shamali M, Abbasinia M, Østergaard B, Konradsen H (2019) Effect of minimally invasive endotracheal tube suctioning on physiological indices in adult intubated patients: an open-labelled randomised controlled trial. Aust Crit Care 32:199–204. https://doi.org/10.1016/j.aucc.2018.03.007
15. Landa JF, Kwoka MA, Chapman GA et al (1980) Effects of suctioning on mucociliary transport. Chest 77:202–207. https://doi.org/10.1378/chest.77.2.202
16. Kollef MH, Prentice D, Shapiro SD et al (1997) Mechanical ventilation with or without daily changes of in-line suction catheters. Am J Respir Crit Care Med 156:466–472. https://doi.org/10.1164/ajrccm.156.2.9612083
17. Nakstad ER, Opdahl H, Heyerdahl F et al (2017) Manual ventilation and open suction procedures contribute to negative pressures in a mechanical lung model. BMJ Open Respir Res 4:e000176. https://doi.org/10.1136/bmjresp-2016-000176
18. Caruso P, Denari S, Ruiz SA, Demarzo SE, Deheinzelin D (2009) Saline instillation before tracheal suctioning decreased the incidence of ventilator-associated pneumonia. Crit Care Med 37:32–38
19. Sutherasan Y, Vargas M, Pelosi P (2014) Protective mechanical ventilation in the non-injured lung: review and meta-analysis. Crit Care 18:211. https://doi.org/10.1186/cc13778
20. Bassi GL, Martí JD, Comaru T et al (2019) Short-term appraisal of the effects and safety of manual versus ventilator hyperinflation in an animal model of severe pneumonia. Resp Care 64:760. https://doi.org/10.4187/respcare.06487