Effects of tracheostomy on respiratory mechanics in critically ill patients requiring prolonged mechanical ventilation

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ABSTRACT

Background: Tracheostomy is a common emergency procedure done in critically ill patients who require prolonged mechanical ventilatory support.

Aim: To determine the effects of tracheostomy on respiratory mechanics, work of breathing (WOB) and arterial blood gases before and after tracheostomy in critically ill patients.

Methods: A before-and-after trial of 20 patients undergoing tracheostomy for failed extubation. After surgical tracheostomy, the endotracheal tube (ETT) was replaced by a tracheostomy tube (TT) of the same internal diameter. Respiratory mechanics, work of breathing (WOB) and arterial blood gases were recorded one day before and 24 hours after tracheostomy. Statistical analysis: Comparisons of the parameters were performed with the aid of unpaired t-tests, Mann-Whitney test, or Wilcoxon ranksum tests ($P < 0.05$).

Results: The peak inspiratory pressure (PIP) decreased and dynamic compliance (Cdyn) improved. The airway resistance decreased; the work of breathing per liter of ventilation performed by the ventilator also decreased after tracheostomy. However, there were no statistically significant changes noted in the plateau pressure (Pplat), mean airway pressure (MAP) and static compliance (Cstat). Differences for PaO_2, PaO_2/FiO_2, $PaCO_2$ and pH were not statistically significant ($P > 0.05$).

Conclusions: After tracheostomy, changing the ETT with TT of similar internal diameter results in a decreased PIP and ventilator WOB. There is an increase in Cdyn . The Pplat and Cstat do not change significantly. Overall, this amounts to a favorable decrease in the respiratory system's resistance and a significant increase in its dynamic compliance. Resistive component of work of breathing is decreased.

Keywords: tracheostomy, weaning, mechanical ventilation, critically ill.

INTRODUCTION

Tracheostomy is one of the oldest known surgical procedures, the first reference to this can be found in the *Rig-Veda*, written in 1500 BC.[1] Chevalier Jackson described the classic modern-day surgical approach for tracheostomy in 1909.[2] Percutaneous tracheostomy has been in vogue since the 1980s as an alternative to surgical tracheostomy and has gained widespread acceptance over the past decade.[3] Critically ill patients with respiratory failure tolerate short-term tracheal intubation well with minimal complications, however, longer (>1 week) mechanical ventilation is associated independently with adverse outcome.[4] Tracheostomy is often performed as an elective procedure in critically ill patients requiring prolonged mechanical ventilation.[5] The timing of tracheostomy for an individual patient, however, is a complex decision. The standard of care has varied considerably over the years, and the current trend recommend within the first week of tracheal intubation.[6] It facilitates weaning, improve patient comfort and reduce the need for sedation during the weaning period.[7] Tracheostomy reduces both respiratory dead space and 'the work of breathing'[8] whereas endotracheal tubes (ETTs) increase dead space and elevate airway resistance, which could lead to excessive ventilatory support. The exact mechanism by which tracheostomy facilitates weaning is however ill-defined. ETTs contribute significantly to total airflow resistance and that *in vivo* resistance of ETTs exceeds the *in vitro* because of secretions, head or neck position, tube deformation, or increased turbulence.[9] Tracheostomy tube (TT) being much shorter should therefore may be associated with improved respiratory mechanics. The present study was aimed to assess respiratory mechanics and arterial blood gases before and after tracheostomy in a group of critically ill patients requiring prolonged mechanical ventilation in the intensive care unit (ICU) of an Eastern Indian university teaching hospital.

MATERIAL AND METHODS

The study was conducted between August 2011 and July 2012, after approval by the Institutional Ethics Committee. Twenty consecutive patients of either sex, admitted to the (ICU), requiring prolonged mechanical ventilation and failed extubation in spite of achieving weaning criteria (PaO2 > 55 mm Hg; pH > 7.30; and respiratory rate < 30/min on room air, rapid shallow breathing index (RSBI) (respiratory rate divided by tidal volume) between 60 to 105) and who needed tracheostomy as per current consensus[10] were included in the study.

Patients with skin infection in neck region, and prior major neck surgery which completely obscured the anatomy, subcutaneous emphysema and coagulopathy were excluded from the study. The traecheostomy was planned after informed written consent from patient or their guardian. Tracheostomy was performed under general anaesthesia. After tracheostomy, the ETT was replaced by a TT of the same internal diameter. All patients were ventilated with Maquet Servo-i adult ventilators. Tidal volume was set at 6–8 ml/kg and the fraction of inspired oxygen (FiO_2) was adjusted for each patient so as to keep the oxygen tension of arterial blood (PaO_2) at 60 mmHg or more. All patients were studied while spontaneously breathing in the pressure-support (PS) ventilation mode.

Mean airway pressure (MAP), peak inspiratory pressure (PIP), plateau pressure (Pplat), positive end-expiratory pressure (PEEP), tidal volume (TV), flow rates (Vi), partial pressure of arterial oxygen (PaO2) and partial pressure of arterial carbon dioxide (PaCO2) and arterial blood pH were recorded one day before and 24 hours after tracheostomy.

Statistics: Data are expressed as mean ± standard deviation. Binary end points were analyzed by means of a Fisher's exact test. Continuous variables were compared with the use of unpaired t-tests, Mann-Whitney test (independent samples), or Wilcoxon ranksum tests (paired samples). All odds ratios and their corresponding 95% confidence intervals were calculated according to the profile-likelihood method. All '*p*' values were 2-tailed and '*p*' values of < 0.05 were considered statistically significant.

RESULTS

The mean age of patients was 46.5 ± 12.6 years. The duration of ICU stay was 22.7 ± 6.1 days, duration of oro-tracheal intubation was 13.5 ± 5.1 days and the duration of mechanical ventilation before the tracheostomy was 12.6 ± 5.2 days. Almost 50% of the patients were diagnosed with traumatic brain injury in coma, followed by COPD.

The PIP decreased and C_{dyn} improved after tracheostomy. The airway resistance decreased and there was a decrease in work of breathing per liter of ventilation performed by the ventilator after tracheostomy. However there were no statistically significant changes noted in the P_{plat}, MAP and C_{stat} before and after tracheostomy. Differences for PaO2, PaO2/FiO_2, PaCO2 and pH were not statistically significant. (Table- 1)

DISCUSSION

In the present study the peak inspiratory pressure decreased and dynamic compliance improved after tracheostomy. Like our study, Lin and co-workers[11] also found the peak inspiratory pressure decreased after a tracheotomy.

The airway resistance decreased after tracheostomy. Wright and co-workers[9] demonstrated that the resistance of endotracheal tubes is greater when measured *in vivo* compared with *in vitro*. This increased resistance was ascribed to increased airflow turbulence from luminal secretions and from increased tube angulation and deformation due to the distortion of the

Table 1: Pre- and Post Tracheostomy respiratory mechanics. *

Parameters	Unit	Pre-tracheostomy	Post tracheostomy	P value (Mann-Whitney test)
Mean airway pressure	cm H2O	3.45 ± 1.51	3.17 ± 1.45	P = 0.15
Peak inspiratory pressure	cm H2O	28.95 ± 2.66	17.60 ± 2.62	P < 0.01
Plateau airway pressure	cm H2O	18.00 ± 1.86	17.25 ± 3.17	P = 0.39
Dynamic compliance	ml/cm H2O	16.70 ± 1.99	32.77 ± 5.54	P < 0.01
Static compliance	ml/cm H2O	30.89 ± 4.39	33.92 ± 8.09	P = 0.15
Work of breathing	J/L	1.36 ± 0.19	0.67 ± 0.29	P < 0.1
Airway resistance	cmH2O/L/s	28.87 ± 2.66	17.52 ± 2.62	P < 0.1
PaO2	mmHg	82.65 ± 10.67	88.60 ± 8.91	P = 0.07
PaCO2	mmHg	34.11 ± 3.80	33.38 ± 3.56	P = 0.56
PaO2/FiO2	-	352.3 ± 53.05	378.4 ± 54.01	P = 0.13
pH	-	7.38 ± 0.12	7.45 ± 0.13	P = 0.12

* Results are expressed as means ± standard deviations. PaO_2, partial pressure of arterial oxygen; $PaCO_2$, partial pressure of arterial carbon dioxide; FiO_2, fraction of inspired oxygen; pH, pH of arterial blood.

endotracheal tube in the upper airways. Due to these reasons, the replacement of ETT with a TT of similar internal diameter may be decreasing the airway resistance.

In the present study we found a decrease in work of breathing (WOB) per liter of ventilation performed by the ventilator after the tracheostomy. Diehl and co-workers[12] measured the WOB in eight patients before and after tracheostomy and found a significant decrease in WOB after tracheostomy. Davis and co-workers[13] observed a modest reduction in mean WOB per liter of ventilation, WOB per minute and airway resistance after tracheostomy as compared to breathing via an endotracheal tube. The beneficial effects were magnified, however, as the respiratory rate increased.

The present study also revealed that after surgical tracheostomy, there is a favorable decrease in the respiratory system's resistance as well as a significant increase in its dynamic compliance. The elastic component of the respiratory mechanics as described by the plateau pressure and static compliance are however not changed significantly.

The shorter length of a TT compared to an ETT is associated with less airway resistance when measured *in vitro* during constant flow and oscillatory conditions.[14] Tracheostomy does reduce dead space, in comparison with the non-intubated state; however, the difference between an ETT and a TT with respect to dead space is small.[13] Although the small radius of curvature of TT increases turbulent airflow and airway resistance, the short length of TT more than compensates for airflow turbulence. The overall lower airway resistance may decrease the loads imposed on the respiratory system and thereby promote weaning from mechanical ventilation.

CONCLUSION

Changing the endotracheal tube with a tracheostomy tube of similar internal diameter results in a decreased PIP, ventilator WOB, and increased C_{dyn}. However, the P_{plat} and C_{stat} do not change significantly. Overall this amounts to a favourable decrease in the respiratory system's resistance and a significant increase in its dynamic compliance. Resistive component of work of breathing is decreased. Whether these physiological benefits are of clinical importance in enhancing weaning success still remains unanswered.

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