Clinical Bibliography - TrachFlush

1 DISCLAIMER

This bibliography is a literature reference for users and represents selected relevant publications, without any claim to completeness, for TrachFlush.

2 CATEGORIES

The selected relevant publications have been categorized into 5 categories:

Category	Description of literature
Secretion removal using TrachFlush	Publications demonstrating TrachFlush can remove secretions below and above (subglottic) the cuff, and reduce the need for tracheal suctioning
VAP prevention using a cuff controller	Publications demonstrating using an automatic cuff pressure manager or manually maintaining the cuff pressure prevents and reduces VAP with up to 50%.
Discomfort and side effects of tracheal suctioning in the ICU	Publications demonstrating the side-effects of tracheal suctioning and the patients' recollection of their ICU stay
Secretion removal with manual TrachFlush maneuver	Publications demonstrating performing the TrachFlush maneuver removes subglottic secretions
Preventing and reducing VAP with subglottic suctioning	Publications demonstrating removing subglottic secretions prevents and reduces VAP

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4 Secretion removal using TrachFlush

4.1 Efficacy of an automated secretion removal technology at different inspiratory pressures

Anne H. Nielsen, Dan S. Karbing, Christoffer G. Sølling, Robert R. Winding, Stephen E. Rees, and Nilanjan Dey.

Respir Care 2023;68(11):1502-1509,
https://rc.rcjournal.com/content/early/2023/04/28/respcare.10850

Background	Endotracheal suctioning is resource demanding, causes patient discomfort, and is associated with adverse effects. A new artificial cough method has been developed for automated secretion removal by using rapid deflation and inflation of the endotracheal tube cuff during the inspiratory phase of mechanical ventilation. This method has been evaluated in a bench model and in animals but not in human subjects. The aim of this study was to investigate whether this method can remove the need for endotracheal suctioning in subjects and whether this is dependent on ventilator settings.
Methods	This prospective, non-controlled study recruited 20 subjects on invasive mechanical ventilation. On the clinical need for endotracheal suctioning, the automatic cough procedure was applied 3 times over 30 s, with this repeated at higher ventilatory pressure and lower respiratory frequency if considered unsuccessful. Success was determined by removal of the clinical need for suctioning. Subject safety and comfort was measured by using the Critical-Care Pain Observation Tool before and after the procedure, and negative effects were recorded. To assess intra-subject variability, the procedure was performed on 3 different occasions for each subject.
Results	The procedure was successful in 18 of 20 subjects (90%), with mean subject success rates of 53% at low settings (peak inspiratory pressure 21.8 +/- 3.8 cm H2O) and 83% at high settings (peak inspiratory pressure 25.6 +/- 3.6 cm H2O). The Critical-Care Pain Observation Tool category remained unchanged in 30 procedures (77%), improved in 7 (18%), and deteriorated in 2 (5%).
Conclusion	This study illustrated the potential for significant reduction in the clinical need for endotracheal suctioning after the use of an automated artificial cough procedure at both low and high peak inspiratory pressures, and that was well tolerated.

4.2 A prospective, longitudinal study evaluating the efficacy of an automated secretion removal technology

Jante S. Sinnige, Dan S. Karbing, Christel M. A. Valk, Marcus J. Schultz, Stephen E. Rees, and Frederique Paulus.

Respir Care 2024;69(8):931-936, https://rc.rcjournal.com/content/early/2024/01/31/respcare.11584

Background	Endotracheal suctioning causes discomfort, is associated with adverse effects, and is resource-demanding. An artificial secretion removal method, known as an automated cough, has been developed, which applies rapid, automated deflation, and inflation of the endotracheal tube cuff during the inspiratory phase of mechanical ventilation. This method has been evaluated in the hands of researchers but not when used by attending nurses. The aim of this study was to explore the efficacy of the method over the course of patient management as part of routine care.
Methods	This prospective, longitudinal, interventional study recruited 28 subjects who were intubated and mechanically ventilated. For a maximum of 7 d and on clinical need for endotracheal suctioning, the automatic cough procedure was applied. The subjects were placed in a pressure-regulated ventilation mode with elevated inspiratory pressure, and automated cuff deflation and inflation were performed 3 times, with this repeated if deemed necessary. Success was determined by resolution of the clinical need for suctioning as determined by the attending nurse. Adverse effects were recorded.
Results	A total of 84 procedures were performed. In 54% of the subjects, the artificial cough procedure was successful on > 70% of occasions, with 56% of all procedures considered successful. Ninety percent of all the procedures were performed in subjects who were spontaneously breathing and on pressure-support ventilation with peak inspiratory pressures of 20 cm H_2O. Rates of adverse events were similar to those seen in the application of endotracheal suctioning.
Conclusion	This study solely evaluated the efficacy of an automated artificial cough procedure, which illustrated the potential for reducing the need for endotracheal suctioning when applied by attending nurses in routine care.

4.3 An artificial cough maneuver to remove secretions from below the endotracheal tube cuff

Alberto Zanella, Gaetano Florio, Emanuele Rezoagli, Martina Pastore, Paolo Cadringer, Osvaldo Biancolilli, Eleonora Carlesso, Vittorio Scaravilli, Giuseppe Ristagno, and Antonio M. Pesenti.

Respir Care 0;0(0):1, https://pubmed.ncbi.nlm.nih.gov/30622174/

Background	Endotracheal suctioning is mandatory to prevent complications caused by the retention of tracheal secretions. Endotracheal suctioning is often performed late, when patients show signs of respiratory and hemodynamic alterations. We conceived a prototype device that, when synchronized with the ventilator, automatically removes secretions collected below the endotracheal tube (ETT) cuff, thus avoiding endotracheal suctioning. The aim of our investigation was to assess the performance of this novel prototype in vitro.
Methods	Three studies were performed to examine the characteristics of the prototype. We tested device's ability to generate an effective artificial cough flow (artificial cough maneuver) > 1 L/s by rapidly deflating the ETT cuff within the time of a sustained inflation (at 30 and at 40 cm H2O) (cough flow study). We also tested the prototype's ability to remove the fluid positioned below the ETT cuff using saline dye (fluid removal study), and to prevent the aspiration of saline dye from above the ETT cuff during the deflation phase of the ETT cuff (aspiration study). The trachea model was positioned at 45° in the aspiration study, and horizontally in the other two studies.
Results	In the cough flow study, the prototype provided an effective artificial cough maneuver, with a mean SD of 1.78 +/- 0.19 L/s (range, 1.42–2.14 L/s). The tracheal pressure after ETT cuff deflation never decreased below the PEEP level. In the fluid removal study, the prototype cleared the fluid from below the ETT cuff and the experimental trachea. No fluid was aspirated from the area above the ETT cuff toward the lower airways.
Conclusion	We conceived an system capable of automatically expelling fluid from below the ETT cuff outside an experimental trachea by generating an artificial cough maneuver. This system may decrease the use of endotracheal suctioning and its complications. Future in vivo studies are needed to confirm this first in vitro evaluation.

4.4 Efficacy and safety of trachflush artificial cough maneuver for fluid removal in simulated breathing

Introduction	Suctioning through the endotracheal tube (ETT) to remove secretion has several side effects. TrachFlush (AW Technologies) applies a method for secretion removal by Zanella et al. [1] by artificial coughs (ACs) implemented by rapid ETT cuff deflation/inflation during inspiration. Peak airway flow (Qpeak) ≥60 L/min is necessary to displace secretion [2]. Zanella et al. showed at peak inspiratory pressure (PIP) of 30-40 cmH2O AC Qpeak≥60 L/min and safe fluid removal with no aspiration. This study evaluated TrachFlush performance at PIP of 20-40 cmH2O.
Methods	Nine scenarios were simulated with 3 PIP (20, 30 and 40 cmH2O) and 3 lung conditions (healthy, low compliance (CRS) and high resistance (RAW)). An artificial lung (QuickLung Breather, IngMar Medical) was ventilated in pressure control (PC) (RR=7 min-1, I:E=1:2, PEEP=5 cmH2O) via a Ø=7.5 mm ETT in an artificial trachea (25 cm, Ø=19 mm PVC tube) with resistance 3.7 cmH2O/L/s at 60L/min. Qpeak was measured with the trachea horizontal during 5 ACs. We analysed the middle 3 ACs. Fluid removal and aspiration at PIP 20 and 30 cmH2O were visually assessed over 3 ACs, with trachea horizontal and 2 mL dyed saline injected between ETT cuff and lung or trachea at 45o and 2 mL saline injected above cuff, respectively.
Results	The figure shows effect of PIP and lung condition (CRS and RAW in cmH2O and L/cmH2O/s) on Qpeak and AC time with Q≥60 L/min. Qpeak≥60 L/min for >0.5 s in all scenarios. PIP and lung condition ($p<0.01$) were important linear regression predictors for Qpeak (multivariate model adjusted $R2=0.873$, $p<0.001$). The saline was fully removed in all scenarios, and no fluid aspiration was observed in any of the scenarios.
Conclusion	The TrachFlush AC produced sustained and sufficient Qpeak for secretion removal and removed saline and avoided aspiration in all simulated scenarios.

4.5 In vivo evaluation of a new endotracheal tube cuff controller promoting tracheal secretion clearance: preliminary results

Luigi Vivona, Alberto Zanella, Stephen E. Rees, Dan S. Karbing, Marco Bellotti, Gaetano Florio, Federico Sodi, Giogia Caddeo, Mauro Panigada, Antonio Pesenti, and Giacomo Graselli.

https://rc.rcjournal.com/content/67/Suppl_10/3776321

Background	Patients undergoing invasive mechanical ventilation accumulate secretions into the trachea, both below and above the endotracheal tube (ETT) cuff. Therefore, suctioning is required to prevent complications due to secretion retention, but such a procedure is not without risks. TrachFlush is a new cuff controller synchronized with the mechanical ventilator that generates an artificial cough maneuver by briefly deflating and re-inflating the ETT cuff within the inspiratory time.
Methods	7 patients admitted to our general intensive care unit were enrolled in the study and connected to TrachFlush (expected sample size 72 patients). A sigh (total inspiratory pressure 35 cmH2O, inspiratory time about 2 seconds, once per minute) was introduced if not present. The ETT cuff pressure was set to 25 cmH2O. We performed 3 artificial cough maneuvers during 3 consecutive sighs. The primary aim of the present study was to estimate the artificial cough flow generated around the ETT cuff, computed as the leaked volume divided by the cuff deflation time (average 1.18 sec), see figure 1. In 4 patients mouth aspiration was performed at the start and end of the study while in 5 patients endotracheal suctioning was performed at the end of the study. The study was approved by local IRB. Data are reported as mean±standard deviation.
Results	Table 1 reports the baseline data and the main results. All patients underwent 3 artificial cough maneuvers. All the artificial cough maneuvers in all patients produced an artificial cough flow ranging from 6.2 to 37.4 l/min. The mean flow was 21±9 l/min. The average of the maximum flow reached in each patient was 28±7 l/min. The maximum flow was recorded predominantly during the third cough maneuver. At the end of the study, in all the 4 patients in which mouth secretions were evaluated, we could detect secretions while endotracheal secretions were present in 4/5 of the patients. In one patient undergoing pressure support ventilation, the artificial cough maneuver stimulated the patient's cough. No complications were recorded during the study.
Conclusion	The tested ETT cuff controller was able to produce a significant artificial cough flow around the cuff promoting the transport of tracheal secretions, either sub-glottal or sub-cuff, into the mouth.

	Baseline								Artificial cough maneuver		Final evaluation	
Patient	ETT #	Sex	Age (y)	Respiratory rate (bpm)	PEEP (cmH_2O)	Ventilatory mode	Tidal volume (ml)	Peak pressure (cmH_2O)	Artificial cough flow (l/min)	MAX artificial cough flow (l/min)	Mouth secretions (0,1,2,3)	Endotracheal secretions (0,1,2,3)
1	7.5	male	19	15	5	Controlled	520	13	16.4±2.8	19.3	NE	NE
2	8	male	63	17	8	Assisted	450	13	10.4±6.4	17.8	1	3
3	7.5	male	63	19	6	Assisted	538	14	24.4±9.3	31	NE	NE
4	7.5	male	46	18	11	Controlled	331	26	28.5±6.7	33.6	NE	2
5	7.5	male	40	12	5	Controlled	653	23	19.8±6.5	25.4	1	0
6	7.5	female	79	15	6.5	Controlled	408	16	26.4±3.6	29	2	2
7	7.5	male	73	26	10	Assisted	504	25	18.7±16.2	37.4	1	1
TOT			55±21	17±4	7±2		486±103	19±6	20.5±9.2	27.6±7.2		

Table1. ETT#: endotracheal tube diameter, PEEP: positive end-expiratory pressure; Mouth and bronchial secretion were measured as 0 no secretions, 1 few secretions, 2 abundant secretions, 3 very abundant secretions; NE: not evaluated.

5 VAP prevention using a cuff controller

5.1 Continuous control of ET cuff pressure and tracheal wall damage randomized controlled animal study

Saad Nseir, Alexandre Duguet, Marie-Christine Copin, Julien De Jonckheere, Mao Zhang, Thomas Similowski, and Charles-Hugo Marquette

Critical Care 2007, 11:R109 (doi:10.1186/cc6142),
https://pmc.ncbi.nlm.nih.gov/articles/PMC2556761/

Background	Intubation is frequently performed in intensive care unit patients. Overinflation of the endotracheal tube cuff is a risk factor for tracheal ischemia and subsequent complications. Despite manual control of the cuff pressure, overinflation of the endotracheal cuff is common in intensive care unit patients. We hypothesized that efficient continuous control of the endotracheal cuff pressure using a pneumatic device would reduce tracheal ischemic lesions in piglets ventilated for 48 hours through a high-volume, low-pressure endotracheal tube.
Methods	Twelve piglets were intubated and mechanically ventilated for 48 hours. Animals were randomized to manual control of the endotracheal cuff pressure (n = 6) or to continuous control of the endotracheal cuff pressure using a pneumatic device (n = 6). In the two groups, we inflated the endotracheal cuff with 50 ml air for 30 minutes, eight times daily. This hyperinflation of the endotracheal cuff aimed at mimicking high-pressure periods observed in intubated critically ill patients. In all animals, the cuff pressure and the airway pressure were continuously recorded for 48 hours. After sacrifice of the study animals, the trachea was removed and opened longitudinally for gross and histological examination. A pathologist evaluated the slides without knowledge of treatment group assignment.
Results	The cuff pressure was significantly lower in piglets with the pneumatic device than in piglets without the pneumatic device (median (interquartile range), 18.6 (11–19.4) cmH2O versus 26 (20–56) cmH2O, *P* = 0.009). No significant difference was found in the percentage of time spent with a cuff pressure <15 cmH2O and that with a cuff pressure between 30 and 50cmH2O. The percentage of time between 15 and 30cmH2O of cuff pressure, however, was significantly higher in piglets with the pneumatic device than in piglets without the pneumatic device (98% (95–99%) versus 65% (44–80%), *P* = 0.002). In addition, the percentage of time with cuff pressure >50 cmH2O was significantly lower in piglets with the pneumatic device than in piglets without the pneumatic device (0% versus 19% (12–41%), *P* = 0.002). In all animals, hyperemia and hemorrhages were observed at the cuff contact area. Histological examination showed no difference in tracheal lesions between animals with and without the pneumatic device. These lesions included deep mucous ulceration, squamous metaplasia and intense mucosal inflammation. No cartilage lesions were observed.
Conclusion	The pneumatic device provided effective continuous control of high-volume, low-pressure endotracheal cuff pressure in piglets mechanically ventilated for 48 hours. In the present model, however, no significant difference was found in tracheal mucosal lesions of animals with or without a pneumatic device. Further studies are needed to determine the impact of continuous control of cuff pressure over a longer duration of mechanical ventilation

5.2 Continuous control of tracheal cuff pressure for VAP prevention: a collaborative meta-analysis of individual participant data

Sadd Nseir, Leonardo Lorente, Miquel Ferrer, Anahita Rouzé, Oswaldo Gonzalez, Gianluigi Li Bassi, Alain Duhamel, and Antoni Torres.

Ann. Intensive Care (2025) 5:43, DOI 10.1186/s13613-015-0087-3,
https://pmc.ncbi.nlm.nih.gov/articles/PMC4658343/

Background	Underinflation of tracheal cuff is a risk factor for microaspiration of contaminated secretions and subsequent ventilator-associated pneumonia (VAP). The aim of this collaborative meta-analysis of individual participant data is to determine the impact of continuous control of *P*cuff on the incidence of VAP.
Methods	Studies were identified by searching PubMed and references of relevant articles. Data from 3 prospective controlled trials (two randomized and one quasi-randomized), which evaluated the impact of continuous control of *P*cuff on the incidence of VAP, were obtained and pooled together. Three different devices were used to continuously control *P*cuff. VAP was diagnosed using clinical, radiologic, and quantitative microbiological criteria. The impact of continuous control of *P*cuff on VAP was assessed by Cox regression analysis, stratified on trial
Results	263 (48.4 %) patients received continuous control of *P*cuff, and 280 (51.5 %) patients received routine control of *P*cuff using a manometer. 36 (13.6 %) VAP were diagnosed in continuous control group, and 72 (25.7 %) in routine care group (HR 0.47, 95 % CI 0.31–0.71, $p < 0.001$). However, heterogeneity was apparent in continuous control effect size across trials ($I2 = 58$ %, $p = 0.085$). The number of patients needed to treat to prevent one VAP episode was 8. No significant impact of continuous control of *P*cuff was found on duration of mechanical ventilation, ICU length of stay, or mortality.
Conclusion	Continuous control of *P*cuff might be beneficial in reducing the risk for VAP. However, no significant impact of continuous control of *P*cuff was found on duration of mechanical ventilation, ICU length of stay, or mortality.

5.3 Continuous endotracheal tube cuff pressure control system protects against ventilator-associated pneumonia

Leonaro Lorente, Maria Lecuona, Alejandro Jiménez, Lisset Lorenzo, Isabel Roca, Judith Cabrera, Celina Llanos, and Maria L. Mora.

Critical Care 2014, 18:R77, http://ccforum.com/content/18/2/R77

Introduction	The use of a system for continuous control of endotracheal tube cuff pressure reduced the incidence of ventilator-associated pneumonia (VAP) in one randomized controlled trial (RCT) with 112 patients but not in another RCT with 142 patients. In several guidelines on the prevention of VAP, the use of a system for continuous or intermittent control of endotracheal cuff pressure is not reviewed. The objective of this study was to compare the incidence of VAP in a large sample of patients (n = 284) treated with either continuous or intermittent control of endotracheal tube cuff pressure
Methods	We performed a prospective observational study of patients undergoing mechanical ventilation during more than 48 hours in an intensive care unit (ICU) using either continuous or intermittent endotracheal tube cuff pressure control. Multivariate logistic regression analysis (MLRA) and Cox proportional hazard regression analysis were used to predict VAP. The magnitude of the effect was expressed as odds ratio (OR) or hazard ratio (HR), respectively, and 95% confidence interval (CI).
Results	We found a lower incidence of VAP with the continuous (n = 150) than with the intermittent (n = 134) pressure control system (22.0% versus 11.2%; p = 0.02). MLRA showed that the continuous pressure control system (OR = 0.45; 95% CI = 0.22-0.89; p = 0.02) and the use of an endotracheal tube incorporating a lumen for subglottic secretion drainage (SSD) (OR = 0.39; 95% CI = 0.19-0.84; p = 0.02) were protective factors against VAP. Cox regression analysis showed that the continuous pressure control system (HR = 0.45; 95% CI = 0.24-0.84; p = 0.01) and the use of an endotracheal tube incorporating a lumen for SSD (HR = 0.29; 95% CI = 0.15-0.56; p < 0.001) were protective factors against VAP. However, the interaction between type of endotracheal cuff pressure control system (continuous or intermittent) and endotracheal tube (with or without SSD) was not statistically significant in MLRA (OR = 0.41; 95% CI = 0.07-2.37; p = 0.32) or in Cox analysis (HR = 0.35; 95% CI = 0.06-1.84; p = 0.21).
Conclusion	The use of a continuous endotracheal cuff pressure control system and/or an endotracheal tube with a lumen for SSD could help to prevent VAP in patients requiring more than 48 hours of mechanical ventilation

5.4 Continuous Control of Tracheal Cuff Pressure and Microaspiration of Gastric Contents in Critically Ill Patients

Sadd Nseir, Farid Zerimech, Clément Fournier, Rémy Lubret, Philippe Ramon, Alain Durocher, and Malika Balduyck.

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https://www.atsjournals.org/doi/10.1164/rccm.201104-0630OC?url_ver=Z39.88-2003&rfr_id=ori:rid:crossref.org&rfr_dat=cr_pub%20%200pubmed

Rationale	Underinflation of the tracheal cuff frequently occurs in critically ill patients and represents a risk factor for microaspiration of contaminated oropharyngeal secretions and gastric contents that plays a major role in the pathogenesis of ventilator-associated pneumonia (VAP).
Objectives	To determine the impact of continuous control of tracheal cuff pressure (Pcuff) on microaspiration of gastric contents.
Methods	Prospective randomized controlled trial performed in a single medical intensive care unit. A total of 122 patients expected to receive mechanical ventilation for at least 48 hours through a tracheal tube were randomized to receive continuous control of Pcuff using a pneumatic device (intervention group, n ¼ 61) or routine care of Pcuff (control group, n ¼ 61).
Measurement and main results	The primary outcome was microaspiration of gastric contents as defined by the presence of pepsin at a significant level in tracheal secretions collected during the 48 hours after randomization. Secondary outcomes included incidence of VAP, tracheobronchial bacterial concentration, and tracheal ischemic lesions. The pneumatic device was efficient in controlling Pcuff. Pepsin was measured in 1,205 tracheal aspirates. Percentage of patients with abundant microaspiration (18 vs. 46%; P ¼ 0.002; OR [95%confidenceinterval], 0.25 [0.11–0.59]), bacterial concentration in tracheal aspirates (mean6SD 1.662.4 vs. 3.163.7 log10 cfu/ml, P ¼ 0.014), and VAP rate (9.8 vs. 26.2%; P ¼ 0.032; 0.30 [0.11–0.84]) were significantly lower in the intervention group compared with the control group. However, no significant difference was found in tracheal ischemia score between the two groups.
Conclusion	Continuous control of Pcuff is associatedwith significantly decreasedmicroaspiration of gastric contents in critically ill patients

5.5 Continuous Versus Intermittent Control Cuff Pressure for Preventing Ventilator-Associated Pneumonia: An Updated Meta-Analysis

Yanshou Wu, MD, Yanan Li, MD, Meirong Sun, BS, Jingjing Bu, BS, Congcong Zhao, PhD, Zhenjie Hu, PhD, and Yanling Yin, MD.

Journal of Intensive Care Medicine 1-11, DOI; 10.1177/08850666241232369

https://journals.sagepub.com/doi/10.1177/08850666241232369?url_ver=Z39.88-2003&rfr_id=ori:rid:crossref.org&rfr_dat=cr_pub%20%200pubmed

Objective	This study aimed to evaluate the effect of continuous control cuff pressure (CCCP) versus intermittent control cuff pressure (ICCP) for the prevention of ventilator-associated pneumonia (VAP) in critically ill patients.
Methods	Relevant literature was searched in several databases, including PubMed, Embase, Web of Science, ProQuest, the Cochrane Library, Wanfang Database and China National Knowledge Infrastructure between inception and September 2022. Randomized controlled trials were considered eligible if they compared CCCP with ICCP for the prevention of VAP in critically ill patients. This meta-analysis was performed using the RevMan 5.3 and Trial Sequential Analysis 0.9 software packages. The Grading of Recommendations Assessment, Development and Evaluation (GRADE) framework was used to assess the level of evidence.
Results	We identified 14 randomized control trials with a total of 2080 patients. Meta-analysis revealed that CCCP was associated with a significantly lower incidence of VAP compared with ICCP (relative risk [RR] =0.52; 95% confidence interval [CI]: 0.37-0.74; P < 0.001), although considerable heterogeneity was observed (I2 =71%). Conducting trial sequential analysis confirmed the finding, and the GRADE level was moderate. Subgroup analysis demonstrated that CCCP combined with subglottic secretion drainage (SSD) had a more significant effect on reducing VAP (RR =0.39; 95% CI =0.29-0.52; P < 0.001). The effect of CCCP on ventilator-associated respiratory infection (VARI) incidence was uncertain (RR =0.81; 95% CI=0.53-1.24; P =0.34; I2 = 61%). Additionally, CCCP significantly reduced the duration of mechanical ventilation (MV) (mean difference [MD] =−2.42 days; 95% CI =−4.71-0.12; P =0.04; I2 =87%). Descriptive analysis showed that CCCP improved the qualified rate of cuff pressure. However, no significant differences were found in the length of intensive care unit (ICU) stay (MD =2.42 days; 95% CI= −1.84-6.68; P=0.27) and ICU mortality (RR =0.86; 95% CI =0.74-1.00; P =0.05)
Conclusion	Our findings suggest that the combination of CCCP and SSD can reduce the incidence of VAP and the duration of MV and maintain the stability of cuff pressure. A combination of CCCP and SSD applications is suggested for preventing VAP

6 Discomfort and side effects of tracheal suctioning in the ICU

6.1 Decreasing the Adverse Effects of Endotracheal Suctioning During Mechanical Ventilation by Changing Practice

Salvatore Maurizio Maggiore MD PhD, Francois Lellouche MD, Claudi Pignataro MD, Emmanuelle Giroud PharmD, Bernard Maitre MD, Jean-Christophe M Richard MD PhDm Francois Lemaire MD, Christian Brun-Buisson MD, and Laurent Brochard MD.

Respir Care 2013; 58(10):1588-1597, https://pubmed.ncbi.nlm.nih.gov/23466423/

Background	Little is known about the incidence of and risk factors for adverse effects from endotracheal suctioning. We studied the incidence and risk factors, and evaluated the effect of suctioning practice guidelines.
Methods	During a 3-month period, in 79 mechanically ventilated subjects, we recorded the adverse effects in 4,506 suctioning procedures. Then practice guidelines were implemented, and 1 year later, during another 3-month period, in 68 subjects, we recorded the adverse effects in 4,994 suctioning procedures
Results	In the first period, adverse effects occurred frequently: oxygen desaturation in 46.8% of subjects and 6.5% of suctionings, hemorrhagic secretions in 31.6% of subjects and 4% of suctionings, blood pressure change in 24.1% of subjects and 1.6% of suctionings, and heart rate change in 10.1% of subjects and 1.1% of suctionings. After guidelines implementation, all complications, both separately and all together, were reduced. The incidence of all complications together decreased from 59.5% to 42.6% of subjects, and from 12.4% to 4.9% of procedures (both $P < .05$). PEEP > 5 cmH2O was an independent risk factor for oxygen desaturation. Receiving > 6 suctionings per day was a risk factor for desaturation and hemorrhagic secretions. The use of guidelines was independently associated with fewer complications
Conclusion	Endotracheal suctioning frequently induces adverse effects. Technique, suctioning frequency, and higher PEEP are risk factors for complications. Their incidence can be reduced by the implementation of suctioning guidelines.

6.2 Discomfort and factual recollection in intensive care unit patients

Johannes P van de Leur, Cees P van der Schans, Bert G Loef, Betto G Deelman, Jan HB Geertzen, and Jan H Zwaveling.

Critical Care 2004, 8:R467-R473 (DOI 10.1186/cc2976, http://ccforum.com/content/8/6/R467

Introduction	A stay in the intensive care unit (ICU), although potentially life-saving, may cause considerable discomfort to patients. However, retrospective assessment of discomfort is difficult because recollection of stressful events may be impaired by sedation and severe illness during the ICU stay. This study addresses the following questions. What is the incidence of discomfort reported by patients recently discharged from an ICU? What were the sources of discomfort reported? What was the degree of factual recollection during patients' stay in the ICU? Finally, was discomfort reported more often in patients with good factual recollection?
Methods	All ICU patients older than 18 years who had needed prolonged (>24 hour) admission with tracheal intubation and mechanical ventilation were consecutively included. Within three days after discharge from the ICU, a structured, in-person interview was conducted with each individual patient. All patients were asked to complete a questionnaire consisting of 14 questions specifically concerning the environment of the ICU they had stayed in. Furthermore, they were asked whether they remembered any discomfort during their stay; if they did then they were asked to specify which sources of discomfort they could recall. A reference group of surgical ward patients, matched by sex and age to the ICU group, was studied to validate the questionnaire.
Results	A total of 125 patients discharged from the ICU were included in this study. Data for 123 ICU patients and 48 surgical ward patients were analyzed. The prevalence of recollection of any type of discomfort in the ICU patients was 54% (n = 66). These 66 patients were asked to identify the sources of discomfort, and presence of an endotracheal tube, hallucinations and medical activities were identified as such sources. The median (min–max) score for factual recollection in the ICU patients was 15 (0–28). The median (min–max) score for factual recollection in the reference group was 25 (19–28). Analysis revealed that discomfort was positively related to factual recollection (odds ratio 1.1; $P < 0.001$), especially discomfort caused by the presence of an endotracheal tube, medical activities and noise. Hallucinations were reported more often with increasing age. Pain as a source of discomfort was predominantly reported by younger patients.
Conclusion	Among postdischarge ICU patients, 54% recalled discomfort. However, memory was often impaired: the median factual recollection score of ICU patients was significantly lower than that of matched control patients. The presence of an endotracheal tube, hallucinations and medical activities were most frequently reported as sources of discomfort. Patients with a higher factual recollection score were at greater risk for remembering the stressful presence of an endotracheal tube, medical activities and noise. Younger patients were more likely to report pain as a source of discomfort

6.3 Patients' recollections of experiences in the intensive care unit may affect their quality of like

Cristina Granja, Alice Lopes, Sara Moreira, Claudia Dias, Altamiro Costa-Pereira, Antonio Carneiro, and for the JMIP Study Group.

Critical Care 2005, 9:R96-R109 (DOI 10.1186/cc3026), http://ccforum.com/content/9/2/R96

Introduction	We wished to obtain the experiences felt by patients during their ICU stay using an original questionnaire and to correlate the memories of those experiences with health-related quality of life (HR-QOL).
Methods	We conducted a prospective study in 10 Portuguese intensive care units (ICUs). Six months after ICU discharge, an original questionnaire on experiences of patients during their ICU stay, the recollection questionnaire, was delivered. HR-QOL was evaluated simultaneously, with the EQ-5D questionnaire. Between 1 September 2002 and 31 March 2003 1433 adult patients were admitted. ICU and hospital mortalities were 21% and 28%, respectively. Six months after ICU discharge, 464 patients completed the recollection questionnaire
Results	Thirty-eight percent of the patients stated they did not remember any moment of their ICU stay. The ICU environment was described as friendly and calm by 93% of the patients. Sleep was described as being good and enough by 73%. The experiences reported as being more stressful were tracheal tube aspiration (81%), nose tube (75%), family worries (71%) and pain (64%). Of respondents, 51% experienced dreams and nightmares during their ICU stay; of these, 14% stated that those dreams and nightmares disturb their present daily life and they exhibit a worse HR-QOL. Forty-one percent of patients reported current sleep disturbances, 38% difficulties in concentrating in current daily activities and 36% difficulties in remembering recent events. More than half of the patients reported more fatigue than before the ICU stay. Multiple and linear regression analysis showed that older age, longer ICU stay, higher Simplified Acute Physiology Score II, non-scheduled surgery and multiple trauma diagnostic categories, present sleep disturbances, daily disturbances by dreams and nightmares, difficulties in concentrating and difficulties in remembering recent events were independent predictors of worse HR-QOL. Multicollinearity analysis showed that, with the exception of the correlation between admission diagnostic categories and length of ICU stay (0.47), all other correlations between the independent variables and coefficient estimates included in the regression models were weak (below 0.30).
Conclusion	This study suggests that neuropsychological consequences of critical illness, in particular the recollection of ICU experiences, may influence subsequent HR-QOL.

7 Secretion removal with manual TrachFlush maneuver

7.1 Evaluation of the safety and effectiveness of the rapid flow expulsion maneuver to clear subglottic secretions in vitro and in vivo

Jie Li Msc RRT-NPS RRT-ACCS, Yajuan Zong, Quan Zhou, Huaping Dai MD PhD, and Chen Wang MD PhD.

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Background	Clearing subglottic secretions has been proved to reduce ventilator-associated pneumonia. A manual method named the rapid flow expulsion maneuver was developed to clear subglottic secretions. This study evaluates its safety and effectiveness and analyzes the influential factors.
Methods	This study was composed of 2 parts. In an in vitro study, secretions were instilled directly to the area above the cuff in an intubated tracheal model. Secretions were expelled by the rapid flow expulsion maneuver with different volumes and peak flows in 3 tracheal positions (0, 15, and 30°). At each tracheal position, the maneuver was repeated twice, unless secretions above the cuff were <0.5 mL. In an in vivo study, subglottic secretions were suctioned via subglottic secretion drainage and then were cleared by the rapid flow expulsion maneuver. After the initial maneuver, methylene blue (2 mL) was instilled above the cuff, and the maneuver was performed again. The subject's sputum color was then recorded over 24 h.
Results	In the in vitro study, no aspiration was observed in the 277 maneuvers completed. Subglottic secretions were visibly expelled in 167 of 277 maneuvers (60.3%), and the median clearance efficiencies of the 3 consecutive maneuvers were 39.6, 6.3, and 0.4%. In the 108 first maneuvers, 93 (86.1%) produced visible secretions. Multiple linear regression models were used to identify predictors of clearance efficiency: tracheal position ($P < .001$), flow (P _ .041), and secretion viscosity (P _ .017). In the in vivo study, 77 rapid flow expulsion maneuvers were completed after suctioning via subglottic secretion drainage in 16 subjects, and the maneuvers collected 221.5 mL of secretions. No aspiration was observed over 24 h.
Conclusion	The rapid flow expulsion maneuver was safe and effective to clear subglottic secretions. The first maneuver was the most effective to expel the majority of secretions. Supine position and high peak flow improved the clearance efficiency

7.2 Rapid-flow expulsion maneuver in subglottic secretion clearance to prevent ventilator-associated pneumonia: a randomized controlled study

Ying Li, Xue Yuan, Bing Sun, Hai-chai Li, Hui-wen Chu, Li Wang, Yu Zhao, Xiao Tang, Rui Wang, Xu-yan Li, Zhao-hui Tong, and Chen Wang.

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Background	Following endotracheal intubation, clearing secretions above the endotracheal tube cuff decreases the incidence of ventilator-associated pneumonia (VAP); therefore, subglottic secretion drainage (SSD) is widely advocated. Our group developed a novel technique to remove the subglottic secretions, the rapid-flow expulsion maneuver (RFEM). The objective of this study was to explore the effectiveness and safety of RFEM compared with SSD
Methods	This study was a single-center, prospective, randomized and controlled trial, conducted at Respiratory Intensive Care Unit (ICU) of Beijing Chao-Yang Hospital, a university-affiliated tertiary hospital. The primary outcome was the incidence of VAP, assessed for non-inferiority
Results	Patients with an endotracheal tube allowing drainage of subglottic secretions (*n* = 241) were randomly assigned to either the RFEM group (*n* = 120) or SSD group (*n* = 121). Eleven patients (9.17%) in the RFEM group and 13 (10.74%) in the SSD group developed VAP (difference, − 1.59; 95% confidence interval [CI] [− 9.20 6.03]), as the upper limit of 95% CI was not greater than the pre-defined non-inferiority limit (10%), RFEM was declared non-inferior to SSD. There were no statistically significant differences in the duration of mechanical ventilation, ICU mortality, or ICU length of stay and costs between groups. In terms of safety, no accidental extubation or maneuver-related barotrauma occurred in the RFEM group. The incidence of post-extubation laryngeal edema and reintubation was similar in both groups.
Conclusion	RFEM is effective and safe, with non-inferiority compared to SSD in terms of the incidence of VAP. RFEM could be an alternative method in first-line treatment of respiratory ICU patients.

8 Preventing and reducing VAP with subglottic suctioning

8.1 Subglottic secretion drainage for preventing ventilator-associated pneumonia: an overview of systematic reviews and an updated meta-analysis

Diana P. Pozuelo-Carrascosa, Ángel Herráiz-Adillo, Celia Alvarez-Bueno, Jose Manuel Anon, Vicente Martínez-Vizcaino, and Ivan Cavero-Redondo.

Abstract

Although several guidelines recommend subglottic secretion drainage as a strategy for prevention of ventilator-associated pneumonia (VAP), its use is not widespread. With the aim to assess the effectiveness of subglottic secretion drainage for preventing VAP and to improve other outcomes such as mortality, duration of mechanical ventilation and length of stay in the intensive care unit (ICU) or hospital, an electronic search of the Cochrane Library, MEDLINE, Web of Science and Embase was undertaken. Nine systematic reviews with meta-analysis (in the overview of reviews) and 20 randomised controlled trials (in the updated meta-analysis) were included. In the overview of reviews, all systematic reviews with meta-analysis included found a positive effect of subglottic secretion drainage in the reduction of incidence of VAP. In the updated meta-analysis, subglottic secretion drainage significantly reduced VAP incidence (risk ratio (RR) 0.56, 95% CI 0.48–0.63; I2=0%, p=0.841) and mortality (RR 0.88, 95% CI 0.80–0.97; I2=0%, p=0.888). This is the first study that has found a decrease of mortality associated with the use of subglottic secretion drainage. In addition, subglottic secretion drainage is an effective measure to reduce VAP incidence, despite not improving the duration of mechanical ventilation and ICU and/or hospital length of stay.