Research Article

Comparison of Mechanical Insufflation–Exsufflation and Endotracheal Suctioning in Mechanically Ventilated Patients: Effects on Respiratory Mechanics, Hemodynamics, and Volume of Secretions

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Abstract

Context: Cough assist (CA) is a device to improve bronchial hygiene of patients with secretion in the airways and ineffective cough. **Aims:** To compare the physiological effects and the volume of secretion of mechanical insufflation–exsufflation (CA device) with isolated endotracheal suctioning in mechanically ventilated patients. **Settings and Design:** Randomized crossover trial. **Materials and Methods:** The patients were randomly allocated to the first technique, then the following technique was performed in the next day. We collected the variables related to oxygen saturation, hemodynamics (heart rate, systolic blood pressure, diastolic blood pressure, and mean arterial pressure [MAP]), and respiratory mechanics (tidal volume, minute volume, respiratory rate, and lung compliance and resistance), pre- and postimplementation (immediately and after 15 and 30 min), and the aspirated volume of secretion. **Statistical Analysis Used:** We used two-way analysis of variance followed by the Student–Newman–Keuls *t*-test to compare the variables at different time points. Student's *t*-test was used to compare secretion volumes. All data were stored and analyzed in SPSS for Windows Version 19.0. The significance level was set at 5%. **Results:** Forty-three patients were included in the study. When we compared the results before and after the application of the techniques, we observed no significant difference in lung compliance, pulmonary resistance, MAP, peripheral oxygen saturation, and secretion volume in both groups. **Conclusions:** The mechanical insufflation–exsufflation does not alter respiratory mechanics and hemodynamic stability, and it does not improve airway clearance in mechanically ventilated patients.

Keywords: Cough, mechanical ventilation, secretions

Introduction

Mechanical ventilation in the intensive care setting causes changes in clearance of airway secretions. Endotracheal intubation prevents the patients from closing the glottis, which is an essential step for effective coughing and helps protect the respiratory tract against possible infections.[1,2] This procedure is very effective, but leaves the patients dependent on mucociliary clearance instead of coughing.[3-5] One important care measure in intubated patients is aspiration of secretions through the endotracheal tube. Nevertheless, hygiene can only be maintained in a small portion of the airway.

During the last two decades, bronchial hygiene techniques have attracted increasing scientific interest.[6] However, there is a lack of evidence for superiority of any one bronchial hygiene technique or device.[7] New technologies and advanced methods have been developed to increase

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the effectiveness of mucus clearance in patients with acute respiratory failure, including the use of mechanical insufflation–exsufflation devices. This technique has been described as an effective aid for mucus clearance in patients with chronic muscle weakness or neuromuscular disease.[8-10] The application of positive pressure followed by negative airway pressure (central and peripheral portions) is meant to increase expiratory flow and move secretions toward the glottis, thereby facilitating their removal. In contrast, during tracheal suctioning, negative pressure is applied only in a small, localized area, specifically in the mouth, nasopharynx, trachea, and lumen of the artificial airway (endotracheal or tracheostomy tube).[9]

Usually associated with noninvasive ventilation (NIV), mechanical insufflation/exsufflation has been used to assist bronchial clearance during physiotherapy sessions[10,11] in patients across different age ranges.[10] This technique can be applied noninvasively (e.g., through a face mask) or in patients already connected to an invasive interface; in the latter case, the device will simulate the mechanics of coughing. As patient's participation is not necessary, it can be used in sedated and unconscious patients.[6]

When evaluating bronchial hygiene in intubated patients, increased expiratory flow is still the determining factor for passive removal of secretions in the presence of tracheal tubes which impede glottal closure.[12] Therefore, we believe that cough assist (CA) is more effective in bronchial hygiene and improvement of respiratory mechanics in these patients when compared to conventional tracheal suctioning, since its mechanism involves increased expiratory flow.

Within this context, the aim of this study was to compare the effects of mechanical insufflation–exsufflation using the CA device versus isolated conventional tracheal suctioning (current standard practice for suctioning) on respiratory mechanics, hemodynamic stability, and aspirated secretion volume in mechanically ventilated patients.

Materials and Methods

This randomized crossover trial was conducted at the Intensive Care Unit (ICU) of Hospital Cristo Redentor Hospital. Adult patients of both sexes who were on mechanical ventilation for >48 h, without facial trauma and hemodynamically stable, were eligible for inclusion. The exclusion criteria were history of pulmonary emphysema, the presence of barotrauma, thrombocytopenia, and inability to apply any of the study techniques. From February to April 2014, 43 mechanically ventilated patients were included. The selected patients were randomly allocated, through block randomization, to one of the techniques (conventional tracheal suctioning or mechanical insufflation/exsufflation). In a crossover design, the randomized technique was performed on the 1st day and the second technique on the following day. This study was approved by the Research Ethics Committee of Cristo Redentor Hospital (judgment no. 415,748) and entered into the Brazilian Clinical Trials Registry (accession no. RBR-2bm36r). Written informed consent for participation was obtained from the closest relative of each patient.

Secretion clearance was the primary outcome and was measured as sputum volume (mL).[13] Secretions were collected immediately after the end of the procedure, using a sputum trap attached to the suction system. Sterile saline (10 mL) was flushed through the suction tubing into the trap to clear any secretions in the catheter. The volume of sputum was recorded by subtracting the saline volume from the total volume in the trap.

Tracheal suctioning was performed following the American Association for Respiratory Care recommendations: closed suction system, suction catheter with maximal internal-to-external diameter ratio of 0.5, delivery of 100% oxygen 30 s immediately before and 1 min after the procedure, duration of 15 s, and vacuum pressure of ±150 mmHg.[14]

The mechanical insufflation–exsufflation was performed with the CA device (Philips Respironics, CA-3000, United States), which was applied 5 times in 4 cough cycles in automatic mode, with insufflation and exsufflation pressures of + 40/−40 cmH_2O, respectively. The duration of each phase was 3 s, without pause, and tracheal suctioning was performed as previously described at the end of the procedure. Hyperoxygenation (100% O_2) was performed for 1 min before applying each technique and a 20 s interval was allowed between repetitions. The secretion collected after each procedure was stored in a disposable bronchial secretion collector for later weighing.

For assessment of hemodynamics, we collected data on heart rate, systolic blood pressure, diastolic blood pressure, and mean arterial pressure provided by a standard ICU multiparameter monitor (Infinity Kappa, Dräger, Germany). The respiratory mechanic variables of interest were tidal volume, minute ventilation (VE), respiratory rate, compliance (C), and lung resistance (R), which were collected directly from the mechanical ventilator (Servo, Maquet, Sweden and Evita-4, Dräger, Germany). The total volume of secretion collected was weighed on a precision scale (500-Diamond, Diamond, Korea) by subtracting the weight of the disposable collector from the total measurement.

To detect differences in magnitude (effect size) of 0.90 in the amount of aspirated secretion, with alpha = 0.05 and a statistical power of 80%, the sample size was calculated as 43 patients.[1]

All continuous data were reported as mean and standard deviation. The normality of distribution was assessed using the Kolmogorov–Smirnov test. We used two-way analysis of variance followed by the Student–Newman–Keuls *t*-test to compare the variables at different time points. Student's *t*-test was used to compare secretion volumes. All data were stored and analyzed in Statistical Package for the Social Sciences (SPSS) for Windows Version 19.0. The significance level was set at 5%.

Results

During the preestablished period for data collection, 130 patients were admitted to the 29-bed ICU of the study hospital, for an occupancy rate of 92%. Of these, 43 met the inclusion criteria [Figure 1]. The average patients' age was 51.4 ± 21.2 years; 69.76% were male. The most prevalent reason for ICU admission was traumatic brain injury (32.55%). The median duration of mechanical ventilation was 236.09 ± 362.20 h, and the average length of stay was 10.69 ± 14.51 days [Table 1].

After randomization of each patient, the corresponding procedure (conventional tracheal suctioning or mechanical insufflation–exsufflation) was initiated. Analysis of respiratory mechanics revealed no statistically significant changes in dynamic compliance (CA, $P = 0.58$; conventional tracheal suctioning, $P = 0.78$) [Figure 2] or pulmonary vascular resistance (CA, $P = 0.87$; conventional tracheal suctioning, $P = 0.85$) over the observation period. Likewise, we observed no significant difference between groups with respect to these variables. Comparison of hemodynamic variables again showed no significant differences over time or between groups. The same was observed for peripheral oxygen saturation [Table 2].

Comparison of the volume of secretion (grams) collected using CA versus conventional tracheal suctioning (8.42 ± 3.88 and 7.09 ± 4.15, respectively) revealed no significant difference between techniques ($P = 0.14$) [Figure 3].

Discussion

The main finding of this study was that there is no significant difference in the amount of secretion aspirated when comparing a mechanical insufflator–exsufflator with conventional tracheal aspiration.

The cough is the main component of airway hygiene,[15] and according to Porot and Guérin,[16] cough efficacy is related to peak cough flow (PCF). Increasing the effectiveness of coughing with mechanical equipment is the main therapeutic target in several clinical conditions with impaired cough mechanics, as well as in patients with chronic neuromuscular diseases or critically ill patients with polyneuropathy. The optimization of peak expiratory flow (PEF) that can be provided by such devices is usually the reason for their use.[1,8-11,17,18] Although we did not evaluate the PCF in our study, we believe that the PCF generated by the device during its exsufflation phase was higher than that generated during the tracheal aspiration, since a greater indication of this device has already been described in the literature, such as technique of cough optimization in critical patients, in relation to the others.[19]

Chatwin *et al*.,[8] in a study of 22 patients with neuromuscular disease (muscular dystrophy, spinal muscular atrophy, and

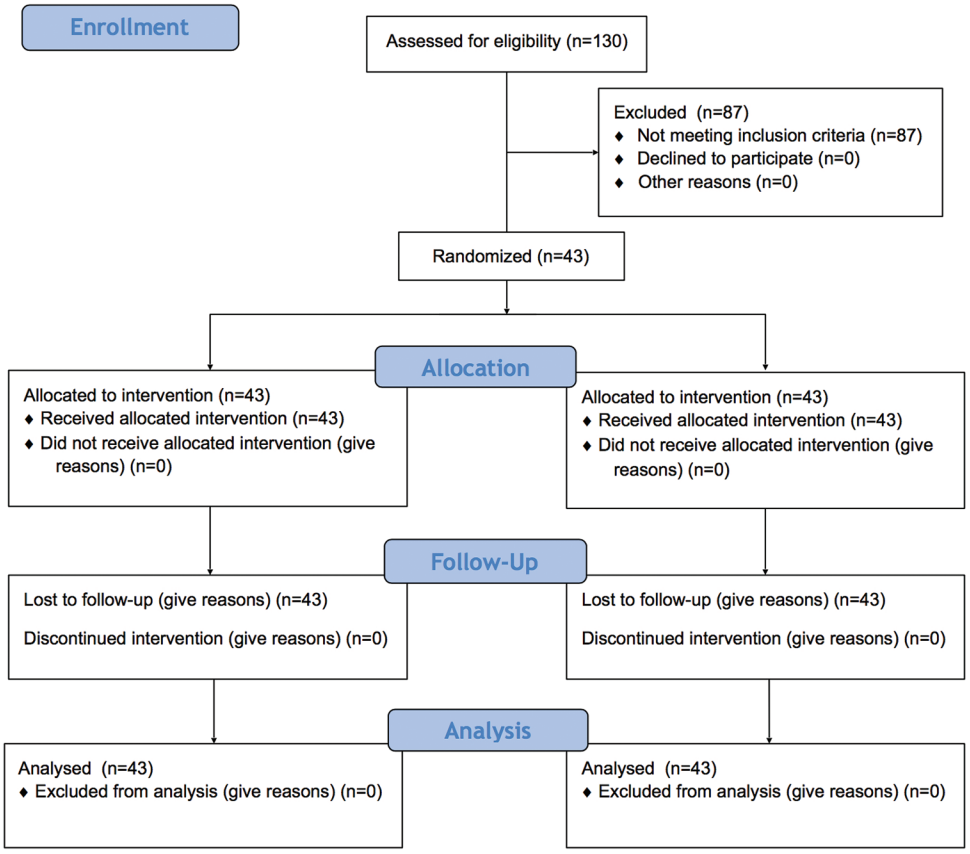

Figure 1: Flowchart of inclusion of patients

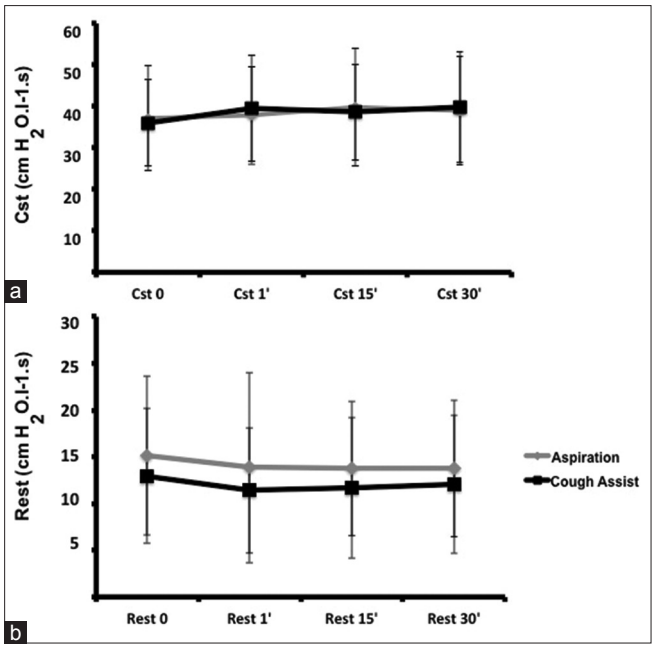

Figure 2: Comparison of respiratory mechanics in the different groups. (a) Cst: Dynamic compliance; (b) Rest: Resistance

Table 1: Baseline patient characteristics

Age, years	51.4±21.2
Male (%)	69.76
Weight, kg	68.4±11.1
Height, cm	169±0.09
BMI, (kg/m^2)	23.92±2.67
Clinical diagnosis, *n* (%)	23.92±2.67
Brain trauma	10 (32.55)
Postoperative	6 (13.95)
Polytrauma	9 (11.62)
Others	18 (41.86)
Days of MV	236.09±362.20
Length of stay, days	10.69±14.51

Data expressed *n* (%) or average (SD). BMI: Body mass index; MV: Mechanical ventilation; SD: Standard deviation

poliomyelitis), noted that PCF values were higher with use of the CA device (set to +15/−15 cmH_2O) than when coughing maneuvers were combined with NIV and manual expiratory assistance in physiotherapy sessions. Similar results were found by Bach,[20] in one of the first studies on the use of the mechanical insufflator–exsufflator. In our study, we used larger pressures, +40/−40 cmH_2O, than the authors mentioned above. However, we believe that the profile of our population, critical patients submitted to the use of artificial airway, may not have reached the PCF generated by the equipment due to the endotracheal tube. Guérin *et al*.[12] and Bourdin *et al*.[21] observed that, when using the CA device set at pressures ranging from +30/−30 to +50/−50 cmH_2O in lung simulators, PEF was impaired in the presence of an artificial airway (endotracheal or tracheostomy tube). In our study, the presence of the artificial airway may also have influenced the

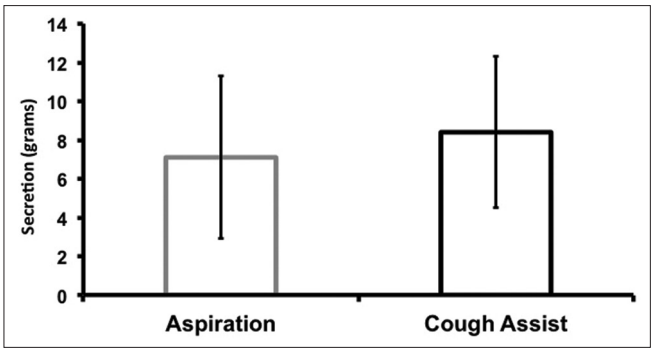

Figure 3: Comparison of the volume of secretion

decrease in PEF generated by the device, thus reducing the ability to remove secretions.

In another study, Sancho *et al*.[22] observed that the CA set to pressures of +40/−40 cmH_2O did not generate greater PCF when compared with manually assisted cough in patients with amyotrophic lateral sclerosis and slight lung function impairment (PCF >4 L/s). However, PCF increased significantly in patients with and without bulbar dysfunction, except in those with PCF <2.7 L/s, a dynamic probably due to collapse of the upper airway during exsufflation. Perhaps, patients with low PCF are unlikely to benefit from the use of this device: even in those who achieve an increase in PCF, the flow generated may still be insufficient to move secretions before the airway collapses.

In the early exsufflation phase, the CA device only applies negative pressure within the airway, which can facilitate early collapse, since the equal pressure point occurs in the most peripheral region of the airway, rather than in the central portion, as occurs when positive pressure is provided during the expiratory phase by other techniques.

We compared the effects of CA versus endotracheal suction in relation to hemodynamic and respiratory mechanics in intubated patients with different diagnoses, in addition to the ability of each technique to remove secretions. Sancho *et al*.[17] compared the same techniques of our study in six patients with amyotrophic lateral sclerosis mechanically ventilated via a tracheostomy. CA was also used at pressures adjusted by +40/−40 cmH_2O. In this study, the variables oxygen saturation, peak inspiratory pressure, mean airway pressure, ventilator work, and the amount of secretion were not significant differences between groups. The small sample size used by the authors may also have contributed to this result.

In the present study, the effects of CA on the outcome of the MV were not evaluated, since the application protocol consisted of a single application to analyze the variables already mentioned. Already, Gonçalves *et al*.[23] used the CA device in 75 extubated patients with diagnoses of chronic obstructive pulmonary disease, congestive heart failure, status post thoracic surgery, thoracic trauma, and sepsis. The aim was to evaluate the effectiveness of the device, which

Table 2: Comparison between the groups regarding respiratory and hemodynamic variables

Characteristics	Control ($n=43$)	Cough assist ($n=43$)	P
V_T (mL)			
Before	529.86±93.46	520.51±102.28	0.65
1’	553.04±116.85	549.65±120.30	0.89
15’	531.27±100.34	538.86±111.54	0.75
30’	527.93±103.75	546.62±118.40	0.42
PPeak, cmH_2O			
Pré	21.16±4.57	21.48±5.14	0.77
1’	21.48±4.53	21.34±4.57	0.91
15’	20.97±4.28	21.20±4.32	0.74
30’	20.88±4.37	21.25±4.22	0.66
RR (brats/min)			
Before	18.16±3.49	17.39±3.33	0.26
1’	21.93±5.24	22.30±6.73	0.75
15’	19.09±3.18	18.44±4.74	0.48
30’	19±3.12	18.04±4.26	0.44
HR (brats/min)			
Before	92.74±18.66	86.23±16.30	0.08
1’	98.86±18.23	96.39±17.79	0.51
15’	93.09±18.26	87.76±16.75	0.15
30’	92.88±18.63	87.65±19.24	0.20
MAP, mmHg			
Before	94.74±15.32	89.69±14.39	0.10
1’	97.46±16.11	94.25±15.77	0.36
15’	92.34±14.10	88.41±14.30	0.20
30’	94±14.89	91.83±14.08	0.47
SpO_2, %			
Before	97.81±2.10	98.34±1.95	0.25
1’	97.11±2.87	97.65±2.70	0.40
15’	97.65±2.33	97.37±2.76	0.58
30’	97.79±2.04	97.74±2.56	1.00

V_T: Tidal volume; PPeak: Peak inspiratory pressure; RR: Respiratory rate; HR: Heart rate; MAP: Mean arterial pressure; SpO_2: Peripheral oxygen saturation; 1’: Assessment carried out in the first minute after the technical implementation; 15’: Assessment carried out 15 min after the technical implementation; 30’: Assessment carried out 30 min after the technical implementation

was adjusted to pressures of +40/−40 cmH_2O, in preventing reintubation in these patients. The result obtained by the author was significantly positive, with a reintubation rate of 17% in the study group compared to 48% in the control group. Similar results were found by Bach *et al.*[24] when using CA in the extubation of patients with restrictive lung disorders. As with any equipment that provides positive pressure, possible complications with the CA device include abdominal distention, worsening gastroesophageal reflux, hemoptysis, chest and abdominal discomfort, acute cardiovascular effects, and pneumothorax. However, these have only rarely been reported in the literature[15] and did not occur at all in our sample.

The present study has some limitations which must be taken into account, such as the use of isolated techniques, as our main goal was to assess the actual performance of both methods in relation to secretion clearance, the short intervention time, and the different brands and models of mechanical ventilators in the ICU, which may have influenced ventilation patterns.

Most of the studies evaluating the use of CA involve patients diagnosed with neuromuscular diseases, as Coutinho *et al*.[25] have demonstrated in their literature review. The authors report that further studies are needed with mechanically ventilated critical patients, and also recommend the use of this device in these patients, since the increase in expiratory flow generated by this equipment is effective in the removal of secretions. They also report that it is a safe and viable strategy when used in the prevention of pulmonary complications, such as retention of secretion and pneumonia, very frequent in ICUs. Further studies with different protocols and sample sizes are needed to demonstrate the possible superiority of mechanical insufflation/exsufflation over other bronchial hygiene techniques or its effectiveness as an isolated method.

In the present study, mechanical insufflation–exsufflation performed with a CA device did not alter respiratory or hemodynamic stability when compared to conventional tracheal suctioning, but also failed to reduce the volume of secretion.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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