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Decreasing adverse effects of endotracheal suctioning during mechanical ventilation by changing practice

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Running head: Complications of endotracheal suctioning

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ABSTRACT

***Background*:** Little is known about incidence and risk factors of endotracheal suctioning-induced adverse effects. The usefulness of suctioning guidelines has not been assessed. Our goal was to determine the incidence and risk factors of endotracheal suctioning-induced complications, and to evaluate if the application of practice guidelines could help to reduce their incidence.

***Methods*:** This was a prospective before and after study in 147 mechanically ventilated patients. During a 3-month period, suctioning adverse effects were recorded daily, for all patients (period I, 79 patients, 4506 suctioning procedures). Then, practice guidelines were implemented and, one year later, the same adverse effects were collected for a second 3-month period (period II, 68 patients, 4994 procedures).

***Results*:** In period I, suctioning-associated adverse effects occurred frequently. The more frequent were oxygen desaturation (patients: 46.8%; procedures: 6.5%), and hemorrhagic secretions (patients: 31.6%; procedures: 4%), followed by blood pressure changes (patients: 24.1%; procedures: 1.6%) and heart rate modifications (patients: 10.1%; procedures: 1.1%). After guidelines implementation, all complications together were reduced (patients: 42.6% vs 59.5%; procedures: 4.9% vs 12.4%, $p<0.05$), as well as each one taken separately. PEEP > 5 cmH_2O was an independent risk factor for oxygen desaturation, while receiving suctioning procedures > 6/day was a risk factor for desaturation and hemorrhagic secretions. Period II was independently associated with a reduced rate of complications.

***Conclusions*:** Endotracheal suctioning frequently induces adverse effects. Technique, frequency of suctioning and high PEEP are risk factors for complications. Their incidence can be reduced by the implementation of practice guidelines.

Abstract word count: 247

Keywords: endotracheal suctioning, closed suctioning system, practice guidelines, mechanical ventilation, acute respiratory distress syndrome, positive end-expiratory pressure

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INTRODUCTION

The presence of an artificial airway during mechanical ventilation makes coughing less effective or not possible. Endotracheal suctioning is therefore needed to avoid accumulation of secretions into the lung and its associated complications. Nevertheless, endotracheal suctioning is an invasive procedure, and is not free from hazards and exceptionally from lethal adverse events [1]. Numerous side effects of endotracheal suctioning have been reported [2-11]. Some old studies on selected population of patients suggested a high frequency of specific adverse events, such as oxygen desaturation and arrhythmia [1, 12]. Leur and coworkers [13] reported a relatively low incidence of some endotracheal suctioning adverse events in a selected population of surgical patients, without acute respiratory distress syndrome (ARDS) and with a short duration of mechanical ventilation. Thus, the incidence and risk factors of adverse effects of endotracheal suctioning in a general medical population of critically ill patients is uncertain.

In 2010, the American Association for Respiratory Care published updated clinical practice guidelines for endotracheal suctioning [9], with the aim of optimizing the procedure and reduce the hazards. Specific suctioning strategies are not systematically used in intensive care units (ICUs) [14], and their usefulness has not been well assessed. Moreover, the optimal approach to reduce endotracheal suctioning-related complications has not been fully clarified [15, 16]. Therefore, we carried out a clinical investigation to: 1) evaluate the incidence of endotracheal suctioning-associated adverse events in mechanically ventilated patients, and 2) determine whether changing the practices through implementation of practice guidelines could decrease their rate. Suctioning-induced adverse events before and after the implementation of practice guidelines were compared using the same methodology. Practice

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guidelines for endotracheal suctioning were drafted independently from those of the American Association for Respiratory Care [9] and before their release.

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MATERIALS AND METHODS

Study Location and Patient Population

The study was conducted in the 26-bed medical ICU of Henri Mondor university hospital (Créteil, France). Institutional Ethics Committee approved the study and waived the requirement for informed consent. All consecutive patients needing mechanical ventilation and aged ≥ 18 years were included during two 3-month periods, from February to April 2000 (Period I) and from April to June 2001 (Period II). According to clinical requirements, patients received sedation by continuous infusion following our local protocol that was the same in the two study periods. They were mechanically ventilated in volume assist/control or pressure support mode. Heat and moisture exchangers were generally used. In all patients, pulse oximetry, electrocardiography, and arterial blood pressure were continuously monitored according to routine practice.

Study Design and Data Collection

Endotracheal suctioning-related adverse events were collected daily during the two 3-month periods. During the first period, endotracheal suctioning was performed according to the usual practice at that time: suctioning procedures were mainly performed routinely every two hours or more often if secretions were visible in the endotracheal/tracheostomy tube; patients were disconnected from the ventilator; the duration of the procedure, the vacuum pressure (frequently > 400 cmH_2O), size of the suction catheter, and depth of suctioning were not standardized; saline was instilled in case of dry, tenacious secretions; no special precaution was used in patients with acute respiratory distress syndrome (ARDS); in general, closed suction systems were not used. In the 1-year interval between the two study periods,

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clinical practice guidelines for endotracheal suctioning were developed during the first month based on the available evidence, and subsequently implemented. The rationale and the feasibility of each guideline were discussed in depth with doctors and nurses until a consensus was reached and, finally, guidelines were described in a written protocol. To facilitate implementation, repeated meetings were organized to educate and to instruct the whole personnel about this protocol. Repeated informal follow-up training was also performed and a medical referent was always available for any questions and technical needs. In the second period, endotracheal suctioning was performed according to practice guidelines. No major change took place in the unit in between these two periods regarding airway and ventilator management. During the two study periods, nurses were instructed to detect and report daily on standardized data collection sheets all adverse events for each suctioning procedure. During and just after the intervention period (Period II), adherence to practice guidelines was also assessed by respiratory therapists and doctors not involved in suctioning procedures. They randomly observed suctioning procedures and, for each procedure, reported if guidelines were followed. A total of 600 observations were performed during night and day. Nurses were not informed of the observers' task.

Compliance to study protocol was assessed daily by investigators and respiratory therapists. This was done by comparing the number of suctioning procedures reported on the daily patient's clinical chart and the number of procedures reported on the specific daily sheet used for the study. In addition, in an attempt to validate the reliability of detecting and reporting adverse effects of endotracheal suctioning following the given instructions, one of the investigators repeatedly observed suctioning procedures and reported if these instructions were followed. Reliability in reporting adverse events of suctioning was expressed in percent

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as: number of correctly reported events / number of observations * 100. A total of 540 observations were performed, 270 in each period.

Clinical Practice Guidelines for Endotracheal Suctioning

Guidelines for endotracheal suctioning were as follows:

1. Frequency of endotracheal suctioning: procedures had to be performed according to patient's needs, and not routinely [17]. Need for endotracheal suctioning was evaluated based on oscillations on the expiratory part of the flow-time curve [18] and tracheal or bronchial respiratory sounds [19, 20]. Ventilator alarms (increased peak airway pressure during volume assist/control ventilation, and decreased tidal volume during pressure-targeted ventilatory modes), presence of secretions into the endotracheal tube or oxygen desaturation, after excluding other possible causes, were also considered as later indicators of the need for suctioning. In paralyzed patients, endotracheal suctioning was performed anyway every four hours, even if the aforementioned signs were absent.
2. Disconnection from the ventilator had to be avoided: suction catheter was introduced through the swivel adapter of the catheter mount or a closed system was used [6].
3. Depth of endotracheal suctioning: to minimize mucosal trauma, shallow suction (limited to the artificial airway and the trachea) was performed instead of deep suction [13]. In practice, a length approximately equal to 8-10 cm (four transverse fingers) of the suction catheter was left outside the endotracheal tube; with a tracheostomy, the suction catheter was introduced up to approximately half its length. In any case, insertion was stopped if an obstacle was met, and suction catheter was retired slightly

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(approximately 1 cm). Suctioning was then started while gradually removing the catheter.

4. Instillation of saline was avoided [21-23]. In case of dry, tenacious secretions, the heat and moisture exchanger was replaced by a heated humidifier. Selective suctioning under direct visualization by fiberoptic bronchoscopy was performed if a mucus plug was suspected.

5. Size of the suction catheter: this had to be adapted to the size of the endotracheal tube, so that the diameter of the suction catheter was less than 50% the internal diameter of the artificial airway [10, 11, 17, 24, 25]. In practice, 16 French suction catheters were used with artificial airways with an internal diameter ≥ 9 mm, 14 French suction catheters were used with 8 or 8.5-mm endotracheal tubes, and 12 French catheters with 7 or 7.5-mm endotracheal tubes.

6. Duration of endotracheal suctioning was limited to less than 10-15 seconds [17, 26, 27]. If needed, suctioning procedure was repeated after a time period sufficient for restoring baseline ventilation and oxygen saturation.

7. Suction pressure had to be set between 200 and 250 cmH_2O (146-182 mmHg) [17, 25, 27, 28].

8. In patients with ARDS: to minimize suctioning-induced lung derecruitment, a closed suction system was used and ventilator auto-triggering was allowed during the procedure [5, 6]. Closed suctioning systems were changed in case of mechanical failure or visible soil only, not routinely [23, 29-31]. Recruitment maneuvers were used in case of persisting hypoxemia after suctioning [4, 32].

A sterile technique was employed at all times. Patient's aspect (sweat, skin color, agitation, etc.), vital parameters (oxygen saturation, heart rate, cardiac rhythm, arterial blood

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pressure), and ventilatory parameters (respiratory rate, tidal volume, peak inspiratory pressure) were monitored during the whole suctioning procedure [17, 27].

Adverse effects of Endotracheal Suctioning

Adverse effects of endotracheal suctioning were defined *a priori*, as follows:

1. oxygen desaturation: a decrease in pulse oximetry greater than 5%;
2. hemorrhagic secretions: blood visible in suctioned secretions;
3. severe hypertension: an increase in systolic blood pressure above 200 mmHg;
4. severe hypotension: a drop in systolic blood pressure below 80 mmHg;
5. severe tachycardia: an increase in heart rate above 150 beats per minute;
6. severe bradycardia: a decrease in heart rate below 50 beats per minute;
7. arrhythmia: any new appearance of sustained supra-ventricular or ventricular arrhythmia.

Statistical Analysis

Results are reported as mean±SD, except when otherwise indicated. Incidence density, expressed per 100 ventilator days, was calculated according to the formula: (number of events / study days) × 100. Dichotomous variables were compared with use of the Chi-square test, and continuous variables with the Student's t test. After assessing normality, the continuous variables were dichotomized using adequate cut-points. Logistic regression analysis was performed incorporating all factors with $p<0.10$ in the univariate analysis. A $p \leq 0.05$ in a two-tailed test was considered to indicate significance. All analyses were performed using Statview statistical software (version 5; SAS Institute Inc., Cary, NC).

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RESULTS

One hundred forty-seven patients were included in the study, for a total of 9,500 suctioning procedures recorded during a total of 1225 ventilator days. During the pre-intervention 3-month period (period I), a total of 4,506 suctioning procedures in 79 patients were collected during 604 ventilator days. After guidelines implementation (period II), 68 patients and 4,994 suctioning procedures were analyzed during 621 ventilator days.

Nurse reliability in detecting and reporting suctioning adverse effects was 94% overall, varying from 91% in period I to 96% in period II. The most common errors in reporting adverse events concerned severe hypotension (20%) and oxygen desaturation (17%). The comparison between the number of suctioning procedures reported on the daily patient's chart and the number of procedures reported on the specific daily sheet used for the study showed that endotracheal suctioning procedures were adequately reported in 95.2% of cases, varying from 94.8% in period I to 95.6% in period II. As shown in Table 1, general characteristics of patients, number of collected suctioning procedures, and outcomes were not statistically different between the two periods.

Adverse Effects of Endotracheal Suctioning before Guidelines Implementation

In period I, 47 patients (59.5%) experienced at least one complication of endotracheal suctioning: oxygen desaturation occurred in 37 patients, hemorrhagic secretions in 25, hypertension in 14, hypotension in 7, tachycardia in 5, and bradycardia in 4 (Figure 1, panel A). One patient experienced transient ventricular tachycardia which resolved spontaneously after suctioning. Adverse effects occurred in 559 procedures and 173 ventilator days (Figure 1, panels B and C), which calculated to a rate of endotracheal suctioning-associated adverse

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effects of 92.5 per 100 ventilator days. Oxygen desaturation (incidence density of 48.3 per 100 ventilator days) and presence of hemorrhagic secretions (incidence density of 30 per 100 ventilator days) were the most frequent adverse effects.

Effect of Practice Guidelines on Endotracheal Suctioning-associated Adverse Effects

Adherence to practice guidelines was 95.9%. The effect of guidelines implementation is shown in Figure 1. Compared to period I, the proportion of patients experiencing any complication of endotracheal suctioning was significantly reduced after guidelines implementation ($p=0.04$). Particularly, fewer patients presented hemorrhagic secretions ($p=0.004$), hypotension ($p=0.04$) and, after adjusting for the length of mechanical ventilation, oxygen desaturation ($p=0.02$). No patient presented any form of arrhythmia during period II. The rate of complicated suctioning procedures was reduced by 61% in period II, with a rate of endotracheal suctioning-associated adverse effects of 39 per 100 ventilator days ($p<0.001$). This reduction concerned all adverse effects, with a decrease of 40% for oxygen desaturation (incidence density of 31.1 per 100 ventilator days) ($p<0.001$), 83% for hemorrhagic secretions (5.5 per 100 ventilator days) ($p<0.001$), 78% for hypertension (1.8 per 100 ventilator days) ($p<0.001$), 94% for hypotension (0.3 per 100 ventilator days) ($p<0.001$), 75% for tachycardia (1.8 per 100 ventilator days) ($p<0.001$), and 67% for bradycardia (0.6 per 100 ventilator days) ($p=0.006$). The proportion of days of mechanical ventilation with complicated suctioning procedures was also significantly reduced in period II ($p<0.001$). Oxygen desaturation and occurrence of hemorrhagic secretions remained the most frequent adverse effects also after implementation of practice guidelines. In period II, the proportion of patients with frequent suctioning procedures (>6/day) was lower, albeit not significantly, than in period I (Table 1).

Risk Factors for Endotracheal Suctioning-associated Adverse Effects

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For the analysis, hypertension and hypotension were grouped together into a "blood pressure changes" category, and tachycardia and bradycardia were grouped into a "heart rate changes" category. The results of the univariate analysis for individual and grouped adverse effects are shown in Table 2. General characteristics were not different between patients with or without endotracheal suctioning-associated adverse effects. For all adverse events, frequency of suctioning was significantly higher in patients with than those without adverse effects. Patients exhibiting oxygen desaturation during endotracheal suctioning had a higher frequency of ARDS, were ventilated with a positive end-expiratory pressure (PEEP) higher than 5 cmH_2O, and had an inspired oxygen concentration (FiO_2) greater than 0.6 more frequently than patients who did not present oxygen desaturation. Anticoagulation for at least 3 days was more frequent in patients with hemorrhagic secretions than in those who did not present such complication.

The results of the multivariate regression analysis are shown in Table 3. Only PEEP > 5 cmH_2O and suctioning procedures > 6/day were independently associated with an increased risk of oxygen desaturation during suctioning. By contrast, not having an ARDS and being in period II were independent protective factors for desaturation. Frequency of suctioning (more than six times a day), but not anticoagulation, was independently associated with an increased risk of hemorrhagic secretions, while period II was a protective factor for this complication. The only independent risk factor for suctioning-induced blood pressure changes was the occurrence of oxygen desaturation.

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DISCUSSION

The main results of this study are that: 1) endotracheal suctioning was frequently complicated, mainly by oxygen desaturation and hemorrhagic secretions; 2) the implementation of practice guidelines reduced the incidence of all adverse effects; 3) frequent suctioning, PEEP > 5 cmH_2O, and ARDS were risk factors for the main adverse events of the procedure (oxygen desaturation and hemorrhagic secretions); 4) oxygen desaturation was a risk factor for hemodynamic alterations during endotracheal suctioning.

The first step of our education initiative aiming at reducing adverse effects of endotracheal suctioning was to assess their incidence during current practice. In this study, a large proportion of mechanically ventilated patients experienced adverse events when endotracheal suctioning was not protocolized. Previous small clinical studies have reported several complications of endotracheal suctioning [1, 3, 5, 6, 12]. In a population of mostly surgical patients with a relatively short length of mechanical ventilation (4-5 days) and without ARDS, Leur et al. found that complications of routine endotracheal suctioning occurred in 38.6% of procedures [13]. When a less invasive suctioning technique was adopted (using a modified suction catheter), complications were reduced to 28.6%. In the first period of our study (routine suctioning), we found a smaller incidence of hypertension and arrhythmia but a larger incidence of oxygen desaturation than previously reported [13]. Differences in the definition of complications, in suctioning techniques, and in patient population likely explain these discrepancies. Instead of relative changes, we used absolute cut-off values for blood pressure and heart rate modifications to facilitate the task of reporting adverse effects for nurses. As a consequence, we could have underestimated these complications. Not surprisingly, we found a greater incidence of oxygen desaturation than in Leur's study, in

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which patients with severe acute respiratory failure were excluded [13]. Our patients were sicker and approximately 20% of them had ARDS (Table 1). In particular, patients' severity was slightly greater, although not significantly, in period II, as suggested by the slightly higher simplified acute physiology score II and greater incidence of ARDS. This can probably explain the somewhat longer duration of mechanical ventilation and of ICU stay and the trend toward a lower ICU survival in period II (Table 1).

Our data suggest the usefulness of practice guidelines to reduce the hazards of endotracheal suctioning [9, 11, 23]. In particular, our results support the clinical value of the recently updated clinical practice guidelines of the American Association for Respiratory Care [9]. Our guidelines, independently developed on the basis of available evidence, are in fact very similar although there may be some difference mainly related to the control of the depth of suctioning. Our method consisted in leaving a length approximately equal to 8-10 cm of the suction catheter outside the endotracheal tube or, in the extreme case of a too deep insertion of the suction catheter inside the trachea so that an obstacle was met, in retiring the suction catheter before applying the negative pressure. This method may be imprecise for determining suction depth and it does not precisely reflect the recent clinical practice guidelines of the American Association for Respiratory Care [9]. The use of suction catheters with length marks would be the best solution to perform shallow suctioning. Unfortunately, we did not have these catheters available in our ICU at the time the study was performed, as it is the case in many ICUs. Our protocol, including the technique of suctioning, was designed to make the individual tasks as easier as possible with the available means. Nevertheless, we observed a quite striking decrease in the rate of hemorrhagic secretions in period II, suggesting that a lower rate of mucosal trauma should have occurred after the implementation of guidelines and supporting the idea that the depth of suctioning was indeed reduced in period II. The bleeding rate could have been even lower with a more precise control of the

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depth of suctioning. The design of our study does not permit to determine the weight of each recommendation on the global impact of guidelines' implementation on adverse effects of endotracheal suctioning.

Endotracheal suctioning-induced oxygen desaturation results from lung derecruitment secondary to both the loss of positive airway pressure due to ventilator disconnection and the application of negative pressure, particularly in patients with ARDS [3, 5, 6, 11]. The duration of suctioning procedure, the level of applied negative pressure, the size of suction catheter, and instillation of saline may also influence the occurrence of lung derecruitment and hypoxia [10, 11, 25-27]. Accordingly, the partial prevention of lung volume fall obtained by avoiding ventilator disconnection or using a closed system in ARDS patients [5, 6, 11], while limiting the duration of procedure, the level of negative suctioning pressure, and the size of suction catheters, can explain the observed decrease in oxygen saturation after guidelines implementation. The presence of blood in suctioned secretions is likely explained by airway mucosal trauma caused by repeated introductions of the suction catheter and application of negative pressure. In agreement with a previous study [13], the reduced depth of suctioning and the limitation of negative pressure provided by our protocol can account for the large decrease in the rate of hemorrhagic secretions in period II. A further limitation of the suction pressure might have been associated with a further reduction of oxygen desaturation and hemorrhagic secretions, but this might have also reduced the efficacy of suctioning in clearing secretions. Blood pressure and heart rate modifications can result from abrupt changes of intrathoracic pressure, the release of endogenous catecholamines secondary to suctioning-induced stress, hypoxemia, and vagal stimulation [1, 13, 33].

To our knowledge, this is the first study assessing risk factors for adverse effects of endotracheal suctioning. This may be useful in identifying patients at increased risk for suctioning-related complications. We found that patients with ARDS, and patients ventilated

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with high PEEP levels were at an increased risk of oxygen desaturation (Table 3). We have previously shown in ARDS patients that lung derecruitment observed after ventilator disconnection was correlated with the level of applied PEEP [6]. Here we could quantify the degree of hypoxemic risk conferred by PEEP > 5 cmH_2O (a 196% increase in risk). In addition, we showed that frequent suctioning procedures (> 6/day) increase substantially the risk of oxygen desaturation and hemorrhagic secretions (Table 3). No risk factor was found for heart rate changes likely because of their low incidence, whereas oxygen desaturation was the only identified prognostic factor for arterial blood pressure alterations (Table 3). This confirms previous data suggesting that hypoxemia plays a key role for the occurrence of this complication [33].

The two suctioning procedures were applied sequentially, in two different periods, and not randomized. Although randomization might have allowed a more rigorous study design, the contemporaneous use of two different suctioning procedures would have been a source of confusion for the nursing staff, potentially leading to major protocol deviations. In addition, the whole study was thought as an education initiative, and study protocol was designed to make the individual tasks as easier as possible. The high compliance obtained with this approach may have compensated at least in part for the less rigorous study design. We did not compare directly the efficacy of the two suctioning procedures, which would require a different study design. All our recommendations were based on the literature, however, and on our own experiments [6].

In conclusion, we have shown that adverse effects of endotracheal suctioning, particularly oxygen desaturation and hemorrhagic secretions, are frequent and can be reduced by the implementation of practice guidelines. We have demonstrated that several factors can be used to identify patients at increased risk of airway suctioning-related complications. By

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doing so, one can pay more attention to high-risk patients and target future intervention studies toward those patients most likely to benefit.

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FIGURE LEGENDS

Figure 1. Proportion of patients exhibiting adverse effects of endotracheal suctioning (A), proportion of complicated suctioning procedures (B), and proportion of ventilator days with complicated procedures (C) before and after implementation of practice guidelines. The sum of proportions for specific complications is greater than the percentage for all complications, because several complications could occur during a single procedure. Data are expressed as mean; standard deviations have been omitted for clarity ($p \leq 0.05$; ** $p \leq 0.01$; † $p < 0.001$ by χ^2 test).

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TABLE 1. General characteristics of the patients, outcome, and number of collected suctioning procedures.

	Before guidelines (n = 79)	After guidelines (n=68)	p value
Age (years)	57.7 ± 17	60.2 ± 15.5	0.36
SAPS II at admission	46.1 ± 16.5	50.5 ± 20.3	0.16
Admission type (%)			
Medical	74.7	79.4	
Surgical	8.9	5.9	0.74
Emergent surgery	16.5	14.7	
Diagnoses (%)			
Respiratory failure	29.1	29.4	0.97
Sepsis or septic shock	27.8	17.6	0.14
ARDS	13.9	23.5	0.13
Heart failure	15.2	5.9	0.07
Cardiac arrest	5.1	8.8	0.37
Hemorrhagic shock	1.3	7.4	0.06
Cerebrovascular disease	2.5	5.9	0.31
Pulmonary embolism	1.3	1.5	0.91
Neurological disease	3.8	0	0.1
Length of mechanical ventilation (days)	10.9 ± 12.2	14.5 ± 19.5	0.18
Length of stay in ICU (days)	17.3 ± 15.4	23.3 ± 32.2	0.14
ICU survival (%)	65	49	0.051
Suctioning procedures	4506	4994	0.23
Suctioning procedures/patient/day	6.6 ± 2.2	6.7 ± 2.8	0.91
Patients with suctioning procedures >6/day (%)	65.8	51.5	0.08
Ventilator days	604	621	0.34
Ventilator days/patient	7.7 ± 7.8	9.1 ± 10.8	0.34

SAPS II: simplified acute physiology score II; ICU: intensive care unit; ARDS: acute respiratory distress syndrome.

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TABLE 2. Results of univariate analysis for complications of endotracheal suctioning.

	Patients with adverse events	Patients without adverse events	p value
Oxygen desaturation	(n = 60)	(n = 87)	
Age (mean ± SD)	59.6 ± 16.5	58.3 ± 16.3	0.65
SAPS II (mean ± SD)	46.3 ± 16.1	49.4 ± 19.9	0.32
ICU survival (%)	58.3	56.3	0.81
ARDS (%)	25	13.8	0.08
PEEP > 5 cmH_2O (%)	58.3	33.3	0.003
FiO_2 > 0.6 (%)	66.7	41.4	0.003
Suctioning > 6/day (%)	81.7	43.7	<0.001
Period (I/II) [a]	37/23	42/45	0.02
Hemorrhagic secretions	(n = 33)	(n = 114)	
Age (mean ± SD)	56.3 ± 16.7	59.6 ± 16.2	0.32
SAPS II (mean ± SD)	44.3 ± 13.9	49.3 ± 19.4	0.17
ICU survival (%)	60.6	56.1	0.65
Anticoagulation > 3 days (%)	36.4	21.9	0.09
Suctioning > 6/day (%)	84.9	51.8	<0.001
Period (I/II)	25/8	54/60	0.004
Blood pressure changes [b]	(n = 26)	(n = 121)	
Age (mean ± SD)	56.1 ± 16.4	59.4 ± 16.3	0.35
SAPS II (mean ± SD)	45 ± 16.1	48.8 ± 18.9	0.35
ICU survival (%)	73.1	53.7	0.07
Oxygen desaturation (%)	73.1	33.9	<0.001
Suctioning > 6/day (%)	80.8	54.5	0.014
Period (I/II)	19/7	60/61	0.029
Heart rate changes [c]	(n = 13)	(n = 134)	
Age (mean ± SD)	60.6 ± 16.6	58.7 ± 16.4	0.69
SAPS II (mean ± SD)	49.1 ± 19.5	48.1 ± 18.4	0.85
ICU survival (%)	46.2	58.2	0.4
Oxygen desaturation (%)	76.9	37.3	0.006
Hemodynamic changes (%)	38.5	15.7	0.04
Suctioning > 6/day (%)	92.3	56	0.011
Period (I/II)	8/5	71/63	0.55

SAPS II: simplified acute physiology score II; ICU: intensive care unit; ARDS: acute respiratory distress syndrome; PEEP: positive end-expiratory pressure; FiO_2: fractional inspired oxygen; period I and II: before and after implementation of guidelines, respectively.
[a] after adjustment for the length of mechanical ventilation.
[b] the blood pressure changes category includes hypertension and hypotension.
[c] the heart rate changes category includes tachycardia and bradycardia.

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TABLE 3. The association between different variables and the occurrence of endotracheal suctioning complications: results of multivariate logistic regression analysis.

	Odds ratio (95% confidence intervals)	p value
Oxygen desaturation (n = 60)		
PEEP > 5 cmH_2O	2.96 (1.26 – 6.95)	0.01
Suctioning > 6/day	6 (2.54 – 14.23)	<0.001
FiO_2 > 0.6	2.25 (0.99 – 5.07)	0.052
No ARDS	0.31 (0.1 – 0.9)	0.03
Period II	0.4 (0.17 – 0.93)	0.03
Hemorrhagic secretions (n = 33)		
Anticoagulation > 3 days	1.45 (0.58 – 3.64)	0.43
Suctioning > 6/day	4.25 (1.45 – 12.44)	0.008
Period II	0.31 (0.13 – 0.78)	0.01
Blood pressure changes (n = 26) [a]		
Oxygen desaturation	4 (1.46 – 11)	0.007
Suctioning > 6/day	1.88 (0.6 – 5.86)	0.28
Period II	0.44 (0.16 – 1.17)	0.09

PEEP: positive end-expiratory pressure; FiO2: fractional inspired oxygen; ARDS: acute respiratory distress syndrome; period II: after implementation of practice guidelines.
[a] the blood pressure changes category includes hypertension and hypotension.

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Figure 1