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# Endotracheal suctioning in hypoxemic patients

## Aspiration trachéale du patient hypoxémique

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**Abstract** Hypoxemic patients are at high risk of developing endotracheal suctioning (ES)-related complications, particularly deterioration of oxygenation and lung derecruitment, which have the potential to worsen lung injury. To prevent or limit these complications, open suctioning should be avoided and closed systems should be preferentially used. To improve cost-effectiveness, the closed system should not be changed routinely but only in case of mechanical failure or visible soiling. Suctioning should be performed only when clinically indicated, avoiding unnecessary procedures. Particular attention should be paid to technical aspects of the procedure, such as suction catheter size, the level of negative pressure, the depth of suction catheter insertion, and the duration of suctioning, which have a huge impact on ES-related complications. Hyperoxygenation and recruiting maneuvers, particularly when performed during suctioning, can be useful in the most severely hypoxemic patients, while hyperinflation before suctioning must be avoided. ***To cite this journal: Réanimation 20 (2011).***

**Keywords** Endotracheal suctioning · Hypoxemia · Oxygenation · Lung derecruitment · Closed suctioning system

**Résumé** Les patients hypoxémiques sont à haut risque de développer des complications liées à l'aspiration trachéale, comme une altération de l'hématose ou un dérecrutement alvéolaire qui peuvent à leur tour, aggraver les lésions pulmonaires. Pour prévenir ou limiter ces complications, il faut désormais préférer les systèmes d'aspiration clos aux systèmes ouverts. Pour améliorer le rapport bénéfice / coût, le système clos ne doit plus désormais être changé régulièrement mais uniquement en cas de problème mécanique ou d'encrassement visible. L'aspiration trachéale ne devrait plus être faite que lorsqu'elle est nécessaire, afin d'éviter toute intervention inutile. Une attention particulière devrait être portée aux aspects techniques de l'aspiration trachéale, comme le diamètre de la sonde d'aspiration utilisée, le niveau de pression négative, la profondeur d'insertion de la sonde et la durée de la manœuvre d'aspiration, tous ces points ayant un impact significatif sur le risque de survenue de complications. L'hyperoxygénation et les manœuvres de recrutement, surtout si réalisées pendant l'aspiration trachéale, pourraient être utiles aux patients les plus hypoxémiques; à l'inverse, l'hyperventilation effectuée avant aspiration devrait être évitée. ***Pour citer cette revue : Réanimation 20 (2011).***

**Mots clés** Aspiration trachéale · Hypoxémie · Hématose · Dérecrutement alvéolaire · Système clos d'aspiration

## Introduction

Endotracheal suctioning (ES) is a procedure consisting in the mechanical aspiration of pulmonary secretions from the endotracheal tube, the trachea, and the lower airways in patients with artificial airways. This procedure is an essential part of airway hygiene therapy in patients undergoing mechanical ventilation in the intensive care unit (ICU), because these patients often show impaired cough reflex and mucociliary clearance, and increased mucus production. Traditionally, ES is performed, after the disconnection of the ventilator circuit, by inserting a suction catheter into the endotracheal tube and applying a negative pressure to the airways to remove tracheobronchial secretions (open suctioning). Alternatively, the procedure can be performed without disconnecting the patient from the ventilator, by introducing the suction catheter through the swivel adapter of the catheter mount (quasi-closed suctioning) or by using a closed suctioning system (closed suctioning) [1]. The closed system is comprised of a sterile plastic sheath-covered

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catheter that is placed in line at the T-piece adaptor and ventilator circuit connections. When the catheter is inserted through the adaptor, it is totally or partially encased, maintaining a closed system. The ES procedure, although essential in preventing endotracheal tube obstruction and pulmonary atelectasis, is not free of risks. In fact, ES can be associated with potentially serious complications, such as hypoxemia and alveolar collapse, hemodynamic disturbances, cardiac disrhythmia, bronchospasm, airway bleeding, and pulmonary infections. Special consideration must be given to these complications to ensure patient's safety.

Patients with hypoxemic acute respiratory failure, in particular those with acute lung injury (ALI) and acute respiratory distress syndrome (ARDS) who are ventilated with high fractions of inspired oxygen (FiO2) and high levels of positive end-expiratory pressure (PEEP), are at greater risk for ES-related complications, especially severe hypoxemia and atelectasis [2,3]. These complications recognize three main pathophysiologic mechanisms. The first mechanism is related to the disconnection of the ventilator circuit and the interruption of mechanical ventilation which abolish the positive pressure inside the lung, thus allowing airway pressure to fall to the atmospheric value and causing a decrease in lung volume [2–4]. The second mechanism is due to the application of a negative pressure during suctioning, which causes airway pressure to fall to subatmospheric values and promotes further lung derecruitment, atelectasis, and bronchoconstriction [2–5]. The amount of negative pressure generated into the airway during suctioning, and the severity of associated complications, is greatly influenced by technical aspects of the procedure, including the size of the suction catheter, the level of vacuum pressure, and the duration and depth of suctioning [6,7]. The third pathophysiologic mechanism responsible for the ES-associated hypoxemia is related to the interruption of oxygen enrichment by the ventilator (i.e., the set FiO2) and the entrainment of ambient air inside the airways, resulting in a dilution of the oxygen content of the gas flow [4]. The fall in lung volume and the occurrence of severe hypoxemia and hypercapnia during and/or after suctioning may in turn induce serious arrhythmias and untoward hemodynamic changes.

In the present review, we will discuss on the technical aspects of the procedure and on the different methods which have been proposed to prevent or to reverse ES-related complications in mechanically ventilated, hypoxemic patients. Recommendations for a safe and effective ES in these patients will be made, based on the available evidence.

## Technical issues

The technique of ES procedure may have a deep influence on the severity of side effects, particularly concerning lung derecruitment and hypoxemia. A particular attention should be paid to the technical aspects, such as frequency, depth, and duration of suctioning, the suction catheter size, and the level of suction pressure, to enhance patient safety.

### Frequency of suctioning

ES should be performed whenever clinically indicated, with special consideration for the potential complications associated with the procedure. In clinical practice, suctioning has been usually performed at some minimum frequency (every 1–2 hours) in order to maintain the patency of the artificial airway used [7–9]. Some studies have suggested that the usual, minimum frequency of 12–24 suctioning procedures per day can be safely reduced. Leur and co-workers [7] performed a randomized, controlled trial in 383 patients requiring mechanical ventilation for more than 24 hours to compare routine ES with on-demand, minimally invasive airway suctioning in terms of clinical outcomes and incidence of suction-related adverse events. Routine ES was performed at a minimum frequency of 3 procedures per day, with preoxygenation, hyperinflation before and after ES, use of a standard 49-cm suction catheter, application of a negative pressure of 200–400 mmHg, and saline instillation. In patients receiving a minimally invasive airway suctioning, ES was performed only when considered clinically indicated, with a 29-cm suction catheter designed to be introduced not beyond the distal end of the endotracheal tube, without preoxygenation, hyperinflation, and saline instillation. No difference was observed in terms of clinical outcome (duration of intubation, length of ICU stay, ICU mortality, and incidence of pulmonary infections). As compared with routine ES, the minimally invasive ES approach was associated, however, with fewer suction-related adverse events, including oxygen desaturation (2.7% versus 2.0%, $p = 0.01$). In another study conducted in a pediatric ICU, Cordero et al. [10] compared frequencies of suctioning, every 4 hours and every 8 hours plus as needed, and found that decreasing ES frequency had no clinically important effect on incidence of nosocomial infections, frequency of reintubation, duration of mechanical ventilation, duration of hospitalization, and neonatal mortality, suggesting that a low-frequency suction regimen can be safely implemented. In another study, Maggiore et al. [6] found that the implementation of practice guidelines, including the recommendation to perform suctioning according to patient's needs only, not at a fixed schedule, was associated with a reduction in ES complications. In particular, an ES frequency greater than 6 per day was a risk factor for the occurrence of oxygen desaturation (odds ratio 6, confidence interval 2.54–14.23; $p < 0.001$) and hemorrhagic secretions (odds ratio 4.25, confidence interval 1.45–12.44; $p < 0.01$). Based on all these data, the updated clinical practice guidelines of the

American Association for Respiratory Care [11] recommend ES to be performed only when clinically indicated to maintain the patency of the artificial airway. In patients with ALI-ARDS, the periodic lung collapse during the suctioning procedure and the alveolar reopening following the restoration of normal mechanical ventilation after ES has been shown to be injurious to the lung [12,13]. Reducing the occurrence of this phenomenon by avoiding unnecessary suctioning procedures is of utmost importance in these patients [2,6].

Because frequency of suctioning should be dependent on the individual patient's requirements, it is important to discuss on how to assess when ES is clinically indicated. Classically, some clinical signs and parameters, such as visible secretions in the airway, increased peak inspiratory pressure during volume-controlled mechanical ventilation or decreased tidal volume during pressure-limited ventilation, deterioration of oxygen saturation, and/or arterial blood gas values and acute respiratory distress after excluding other possible causes, have been used to assess the need to remove pulmonary secretions [2,6–9]. In addition, Jubran et al. [14] showed that a sawtooth pattern on the flow-volume loop on the monitor screen of the ventilator, consisting in a series of accelerations and decelerations on the contour of flow-volume curve as a result of intermittent changes in airway resistances, is a useful parameter to detect the presence of airway secretions in mechanically ventilated patients. More recently, Guglielminotti and co-workers [15] confirmed that a sawtooth pattern on the flow-volume loop is a strong indicator of retained pulmonary secretions, with a sensitivity of 0.82 and a specificity of 0.70. In that study, another good indicator of retained secretions was the presence of respiratory sounds over the trachea caused by accumulated secretions in central airways. At present, a sawtooth pattern on the flow-volume loop and/or the presence of coarse crackles over the trachea are likely to be the best parameters to assess the need for suctioning on an individual basis [11].

## Depth of suctioning

Deep ES may promote a mucosal trauma and airway bleeding, and may also foster major alveolar collapse and hypoxemia due to the transmission of a greater negative pressure to the lung in case of bronchial placement of the suction catheter with the occlusion of more than half the lumen of the bronchial branch [16]. For this reason, it was recommended to perform suctioning in trachea only, inserting the suction catheter until resistance is met (usually at the carina), followed by withdrawal of the catheter by 1 cm before application of negative pressure [6–9]. Recent studies in adults and children suggest that a less invasive, shallow suctioning, performed by introducing the suction catheter to the length of the artificial airway only, may be equally effective than deep suctioning and is associated with less adverse events [7,11,17]. In addition, for a given level of vacuum pressure, the negative pressure transmitted to the trachea is greater when using a short versus long suction catheter, and this may improve the efficacy of a shallow suctioning [18].

## Suction catheter size, level of negative pressure, and duration of suctioning

The size of suction catheter, together with the level of negative pressure and the duration of suctioning, directly influences both the efficacy and the severity of potential complications of ES procedure. The magnitude of the subatmospheric pressure generated into the airways is proportional to the level of negative pressure and to the size of the suction catheter. In fact, for a given diameter of the artificial airway and a given level of applied negative pressure, a larger suction catheter not only generates higher flows but, by narrowing the lumen of the artificial airway, also produces less attenuation of the suction pressure through the airways with the transmission of a greater subatmospheric pressure to the lung and a major fall in aerated volume [19,20]. For this reason, it has been suggested that the diameter of the suction catheter should not exceed one half the inner diameter of the artificial airway [8,16]. Recently, Vanner et al. [21] determined in vitro the tracheal pressure generated with different sizes of suction catheters and of tracheal tubes. In line with previous reports [16], the authors found that tracheal pressure became increasingly negative as the suction catheter outside diameter approached the endotracheal tube internal diameter. When the ratio of the outside diameter of the suction catheter to the inside diameter of the tracheal tubes was 0.5 or less, the negative pressure in trachea was, however, not more than 2 mmHg, which corresponded to a theoretical lung volume loss of 140 ml. Based on these results, the authors formulated recommendations for the sizes of suction catheter to use for each size of tracheal tube (Table 1). These recommendations have been incorporated into the updated clinical practice guidelines of the American Association for Respiratory Care [11].

**Table 1** Recommended suction catheter size according to the size of the endotracheal tube

| ET size ID (mm) | SC size (Fr) | SC color |
|---|---|---|
| 5.0 | 8 | Blue |
| 6.0 | 8 | Blue |
| 7.0 | 10 | Black |
| 8.0 | 12 | White |
| 9.0 | 14 | Green |

ET: endotracheal tube; SC: suction catheter; ID: internal diameter; Fr: French

Data to support an appropriate level of negative pressure are lacking [11]. Common sense and clinical experience suggest that suction pressure should be set as low as possible to limit potential complications and yet sufficient to effectively clear secretions. Negative pressures between 100 and 250 cmH2O have been recommended [8,9,11], but applied suction pressures much greater than 500 cmH2O, together with a largely inadequate monitoring of this parameter, have been reported in clinical practice [22]. As said, the subatmospheric pressure generated in the airways, which is the main factor influencing the amount of lung volume loss and the degree of hypoxemia during ES, is directly proportional to the level of applied negative pressure [19,23], and also depends on the tracheal tube and suction catheter dimensions, the duration of suctioning, and both the amount and quality (thick or thin) of secretions [18]. In a bench study, Morrow et al. [18] demonstrated that increasing suction pressure from −200 mmHg (274 cmH2O) to −360 mmHg (493 cmH2O) increased the amount of secretions suctioned, but it was also associated with the increase of negative pressure inside the lung. Since suction pressure seems, however, to have less influence on lung volume loss than suction catheter size [18,19], it is the present authors' opinion that a negative pressure of 200–250 cmH2O can be safely applied to allow an effective suctioning, provided the appropriate suction catheter size is used and the duration of suctioning is limited [6]. Moreover, when copious secretions are present, it may be justifiable to increase suction pressures (up to 300–350 cmH2O) to allow more effective secretion removal, because the presence of secretions in the catheter limits the amount of negative pressure transmitted in the airways [18].

It is widely recognized that ES duration should be limited to minimize adverse events [8,9,11], in particular lung derecruitment, because also this parameter influences the amount of negative pressure in trachea [18]. However, clinical and experimental data to support a maximum duration of suctioning are scarce and different durations have been reported, ranging from 3 to 30 seconds [2,7]. In a mixed population of critically ill patients, including patients with ARDS, Maggiore et al. [6] showed that the implementation of ES guidelines, including the recommendation to limit the duration of suctioning to less than 20 seconds, was associated with a significant decrease in several adverse events as compared with usual ES without a protocol. In line with this report, the recent clinical practice guidelines of the American Association for Respiratory Care suggest that the duration of the suctioning event should be limited to less than 15 seconds [11].

## Prevention of suctioning-related hypoxemia

Hypoxemia occurs frequently during suctioning, particularly in hypoxemic patients, and it is mainly due to the loss of positive alveolar pressure leading to lung derecruitment [2,4,6,24]. It has been shown that, during open suctioning, the disconnection from the ventilator and the application of negative pressure contribute nearly equally to the lung volume drop observed during the procedure in patients with ALI-ARDS [2]. Different techniques have been proposed to prevent or reverse ES-induced hypoxemia, such as hyperoxygenation, hyperinflation, and lung recruiting maneuvers [8,9,11].

### Hyperoxygenation, hyperinflation, and recruitment maneuvers

Hyperoxygenation consists in delivering 100% oxygen for 30–60 seconds prior to ES and, in the most hypoxemic patients, after the procedure. This can be done preferably by increasing FiO2 setting or by using the temporary oxygen enrichment program on the ventilator [11]. In pediatric patients, Kerem et al. [25] suggested that preoxygenation could prevent the occurrence of hypoxemia during open suctioning. Oh et al. [26] showed a 32% decrease in ES-induced hypoxemia by delivering hyperoxygenation before the procedure while, combining hyperoxygenation before and after the procedure, this complication was reduced by 49%. Although effective in preventing major drops of oxygenation during suctioning, preoxygenation does not prevent or reverse ES-related lung volume fall. On the contrary, delivering 100% oxygen is associated with absorption atelectasis which may enhance the ES-related alveolar collapse. In fact, although Fernandez et al. [27] reported no additive effect of preoxygenation on lung volume changes induced by suctioning, Lu and coworkers [5] demonstrated that hyperoxygenation before suctioning prevented the bronchoconstriction and attenuated the hypoxemia, but also aggravated the increase in areas of nonaerated lung parenchyma associated with the procedure in anesthetized sheep. Moreover, hyperoxygenation before suctioning, while effective in preventing ES-related hypoxemia in patients with mild-to-moderate respiratory failure, may be less useful in the most severe hypoxemic patients, such as those with ARDS, who are already ventilated with high FiO2.

Hyperinflation, usually performed in association with hyperoxygenation, is a procedure used for recruiting pulmonary volume and improves patient's oxygenation capacity before suctioning. It is commonly performed manually by means of a resuscitation bag or using the mechanical ventilator, by delivering high tidal volumes (up to twice the baseline values) or by increasing respiratory rate [8,9]. Conflicting results have been reported concerning the efficacy of hyperinflation to prevent ES-related hypoxemia, and several studies found no benefit with this maneuver [25,26]. Moreover, hyperinflation can be associated with the risk of barotrauma, cardiovascular instability, and increased patient's discomfort, particularly when it is performed by manual ventilation

[9,28,29]. Based on available data, routine use of hyperinflation before suctioning is not recommended [11].

Different from hyperinflation, it has been shown that recruitment maneuvers performed immediately after ES allowed for reversing the lung volume fall and hypoxemia associated with the procedure [2,5,25,30–33]. Different types of recruitment maneuvers have been described. In patients with ALI-ARDS, Dyhr et al. [31] found that a recruitment maneuver, consisting in two inflations up to 45 cmH2O for 20 seconds, with an interval of 1 minute in between, applied after open suctioning, allowed for a fast recovery of end-expiratory lung volume and oxygenation. In an animal model, Lu and coworkers [5] confirmed that a postsuctioning recruitment maneuver, consisting in 20 consecutive breaths of 20 ml/kg volume, could reverse atelectasis and the increase in respiratory resistance resulting from the procedure. The beneficial effects of recruiting maneuvers in preventing ES-related hypoxemia have also been reported during closed suctioning [32]. Although effective in recovering lung volume after ES, these maneuvers do not avoid periodic lung derecruitment. As it has been shown that repetitive alveolar collapse and reopening can be injurious to the lung [12,13], preventing the periodic alveolar derecruitment induced by suctioning could be more clinically relevant than its reversal in patients with ALI-ARDS. Maggiore et al. [2] described an original technique for performing a recruitment maneuver during, not after, ES, consisting in triggering 40 cmH2O pressure-supported breaths synchronous to the application of negative pressure during closed and quasi-closed suctioning. In patients with ALI-ARDS, these authors showed that performing a recruitment maneuver during suctioning prevented major drops in end-expiratory lung volume and in oxygenation, the increase in total respiratory resistance, and even increased alveolar recruitment, as compared with other ES techniques without a recruitment maneuver [2].

## Closed suctioning system

The closed system was introduced into clinical practice in the 1980s to reduce some of the complications associated with the traditional, open suctioning procedure, including environmental contamination and cross-infection, hypoxia, and alveolar derecruitment [34].

### *Effects of closed suctioning on oxygenation and lung volumes*

During open suctioning, the loss in lung volume depends on the abolition of positive airway pressure due to disconnection of the patient from the ventilator, together with the application of a subatmospheric pressure. Ensuing hypoxemia is further worsened by the interruption of oxygen enrichment by the ventilator and the entrainment of ambient air inside the airways. The closed technique does not require patient's disconnection from the ventilator, allowing suctioning to be performed while mechanical ventilation is maintained. The continuation of mechanical ventilation allows in turn to maintain the set FiO2 and, at least in part, the positive pressure inside the airways, thus preserving theoretically oxygenation and lung volume during suctioning.

Several studies have reported that, as compared with open suctioning, the use of a closed system may prevent or limit the ES-related hypoxemia and fall of lung volume [1–3,27,32,35–39]. In fact, it has been shown that, during open suctioning, most of the loss in lung volume occurs just after disconnection, before the application of negative pressure, especially in patients with severe lung disease who have a greater elastic lung recoil and are ventilated with high levels of PEEP [2,40]. Hence, closed suctioning can be particularly useful in these patients. In a study comparing open and closed suctioning, the closed system prevented a deterioration in oxygenation only in patients receiving PEEP >10 cmH2O, while no difference was found between the two systems when PEEP was ≤10 cmH2O [35]. In another study, the authors reported that PEEP >5 cmH2O and diagnosis of ARDS were independent risk factors for the occurrence of oxygen desaturation during suctioning [6]. Two studies assessed the effects of open and closed suctioning on lung volume and oxygenation in patients with ALI-ARDS [2,3]. Cereda et al. reported a lower decrease in end-expiratory lung volume (133 versus 1232 ml) and oxygen saturation (0.2% versus 3.1%) with closed than with open suctioning [3]. This effect was in part related to ventilator autocycling which, in spite of a decrease in tidal volume, allowed to maintain minute ventilation during closed suctioning. In more severe ALI-ARDS patients (arterial oxygen tension to FiO2 ratio: 143 mmHg; PEEP: 12 cmH2O), Maggiore et al. [2] confirmed that the decrease in end-expiratory lung volume was lower during closed and quasi-closed suctioning than during open suctioning (531 and 733 ml versus 1,466 ml, respectively). Lung volume was almost fully recovered 1 minute after suctioning with closed and quasi-closed techniques (−44 and −89 ml, respectively), but not with open ES (−278 ml). Changes in arterial oxygenation saturation paralleled the modifications in lung volume: they were minimal with closed and quasi-closed ES (−2.2 and −1.7%, respectively) and maximal with open ES (−9.2 %). Together with total changes in lung volume, these authors assessed the impact of different ES techniques on true alveolar recruitment and found that recruitment decreased after open and quasi-closed suctioning, remained unchanged using the closed system, and increased when recruitment maneuvers were performed during closed and quasi-closed suctioning.

The effects of closed suctioning depend, however, on the suctioning technique [19], and on the ventilatory mode and settings. If the suction flow exceeds the ventilator flow, negative pressure can be generated into the airways, resulting in lung volume reduction, alveolar collapse, and hypoxemia. Suction flow is in turn dependent on both catheter size and suction pressure: the larger the catheter size and the greater the suction pressure, the higher the suction flow. It was shown that there is an interaction between catheter size and suction pressure in determining lung volume fall with closed suction, but catheter size seems to have the greatest influence [19,41]. In particular, with larger suction catheters and suction pressure of 140 or 200 mmHg, the decrease in lung volume was equivalent with open and closed suctioning [19]. When resulting in ventilator flow lower than suction flow, specific ventilatory mode and settings may promote negative airway pressure and may undo the benefits of closed suctioning on lung volume and oxygenation. This has been reported with pressure-limited modes [38,42], with volume-control ventilation at low inspiratory flow rates [43,44], and with assisted ventilation, in case of patient–ventilator dissynchrony during suctioning [37], particularly when larger than recommended suction catheters were used [38,42,44].

Based on available evidence, it is recommended to avoid ventilator's disconnection and to use closed suctioning systems to perform the procedure in hypoxemic patients ventilated with high levels of FiO2 and PEEP [11], particularly those with ALI-ARDS. This can prevent periodic derecruitment and worsening of hypoxemia, provided adequate suction catheter size (Table 1), level of negative pressure, and ventilator's flow are selected.

### *Efficacy of closed suctioning and effects on pneumonia*

A concern has been raised that the closed system can be less effective than open suctioning in removing secretions. Because ES is a necessary procedure for mechanically ventilated patients to maintain the patency of the artificial airway and to avoid complications of accumulated pulmonary secretions, a decreased efficacy can be harmful. Efficacy of closed suctioning is dependent on ventilator settings, namely the inspiratory flow, the suction catheter size, and the severity of lung disease. High inspiratory flows push in fact the secretions away from the suction catheter and further down the lungs, while larger suction catheters generate greater negative airway pressures, thus improving secretions removal. In a bench study, Lindgren et al. [38] showed that closed suctioning during pressure-controlled ventilation and during a continuous positive airway pressure of 10 cmH2O was markedly less effective than with a continuous positive airway pressure of 0 cmH2O. In an experimental study in rabbits, Copnell et al. [45] found that, irrespective of ventilation mode, the efficacy of the closed system was lower than open suctioning in injured lung, while the two techniques had similar efficacy in normal lung. A single study in ALI patients confirmed that tracheal aspirate mass was lower with closed than with open suctioning (0.6 versus 3.2 g, respectively) using a suction pressure of −200 cmH2O [32]. In that study, however, increasing negative pressure from 200 to 400 cmH2O during closed suctioning improved efficacy (1.7 versus 1.0 g), without affecting oxygenation. Thus, as compared to open suctioning, a greater suction pressure, between 300 and 400 cmH2O, is justifiable during closed suctioning to improve efficacy.

Because of the potential lower risk of contamination due to the fewer breaks of the circuit and a reduced exposure of caregivers to respiratory microorganisms, use of closed suctioning has been proposed as part of a program for prevention of ventilator-associated pneumonia [46]. Recent trials and meta-analysis did not find any difference, however, in the rate of ventilator-associated pneumonia with open and closed suctioning [47–49], even when closed systems were changed not routinely rather than on a daily basis [50]. In addition, it was reported that avoiding daily changes of closed suction catheter is associated with important cost savings [51], particularly when mechanical ventilation is longer than 4 days [50].

**Conflict of interest :** none.

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