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Comparison between open and closed suction systems. A systematic review

Comparação entre os sistemas aberto e fechado de aspiração. Revisão sistemática

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ABSTRACT

Objectives: This study attempted to identify which is the more effective suction system. The objective was to compare open versus closed suction systems according to a systematic review.

Methods: A search of scientific literature was conducted in MedLine, LILACS and Cochrane between 1997 and August 2007 using the key words: endotracheal suction and closed suction. Included were articles that compared the open and closed suction systems used in adult humans and that were randomized and controlled trials.

Results: From the 78 articles identified, only 15 were accepted and described in this review. Nine compared incidence of ventilator-associated pneumonia, six compared oxygen saturation, four compared blood pressure and heart rate, three compared pulmonary volumes, two compared secretion removal and four compared costs. No difference was found in these variables compared: incidence of ventilator associated pneumonia, mortality, intensive care unit length of stay, duration of mechanical ventilation, PaCO2, PaO_2, mean blood pressure, heart rate and secretion removal. However, there were always SpO_2 and pulmonary volume decreases when using the open suction system; and costs were lower in most of the studies that used the closed suction system.

Conclusions: Closed suction system seems to increase the risk of colonization, but has the advantage of not reducing the pulmonary volumes and not entailing a drop of saturation, especially in patients with severe respiratory failure and in the use of higher levels of positive end expiratory pressure.

Keywords: Pneumonia, ventilator-associated; Cost-benefit analysis; Suction/economics; Suction/methods; Ventiladors, mechanical/economics

INTRODUCTION

Tracheal suction is a rather frequent and essential procedure in patients under mechanical ventilation. There are reports that each patient undergoes suction from 8 to 17 times a day. [1-7] During the procedure tracheal secretion is removed to assure adequate oxygen supply and to avoid obstruction of the tube lumen, resulting in increased respiratory work, atelectasias and pulmonary infections. However, there are also adverse effects such as alteration of the heart rate, hypoxemia and ventilator associated pneumonia (VAP).[8] Furthermore, it must be remembered that this is an uncomfortable and invasive procedure.[9]

Two suction systems are available on the market: an open suction sys-

tem (OSS) and a closed suction system (CSS). The OSS is only used once and requires that the ventilator be disconnected. Whereas the CSS use is multiple and permits suction without disconnection. It is positioned between the tracheal tube and the mechanical ventilator circuit and cannot remain in the patient for more than 24 hours.[10] In the United States the CSS has become very popular in the last decade and in the intensive care units (ICU) it is exclusively used in 58% of cases, while the OSS is used exclusively in only 4% of the centers.[11]

In some studies, the OSS seems to have some advantages such as a lower incidence of pneumonia, less physiological changes during the procedure, less bacteria contamination and lower costs.[2,4,12] In an international guide[13] on prevention of VAP, published in 2004, there are recommendations regarding cost reduction with the use of CSS, however this recommendation is only based upon a single study. Those that defend CSS advocate that during suction with OSS the ventilator is disconnected, which, together with the negative vacuum pressure, lead to intense loss of pulmonary volume and subsequent hypoxemia.[14] Until now, there are no concrete evidences off one system being better than the other. Therefore the decision was made to carry out this study and conclude it with a flowchart to orient the choice of the system to be used.

As such, the objective of this study was to compare the closed suction system with the open suction system in relation to the hemodynamic, blood gas exchange, ventilator associated pneumonia, pulmonary volume, secretion removal variables by means of a systematic review and in this way propose a flowchart for the rational utilization of these resources.

METHODS

The systematic review was carried out by a search for scientific articles in the MedLine (International Literature on Health and Science), LILACS (Latin America and the Caribbean Literature on Health and Science) and Cochrane databases encompassing the period from 1997 to August 2007. Keywords used were: endotracheal suction and closed suction.

Articles that compared the open and closed suction systems used in adult humans and that were randomized-controlled trials were included. Pediatric and experimental studies were excluded.

The articles found were assessed by two different, independent reviewers that followed the scientific method appraisal card (Appendix). Studies that had only one reply, yes, on the card were approved by the reviewers and described in this study. Based upon these results, an effort will be made to present a flowchart to orient choice of the suction system best suited for each situation.

RESULTS

Figure 1 particularizes the selection process of articles for this study. Of the 78 studies initially identified, 58 were excluded because they were not relevant, did not compare the two suction systems, dealt with pediatrics or were experimental. Of the 20 remaining articles, four were excluded because they were systematic reviews or meta-analyses, as the studies were the same as those already analyzed here. Only one was excluded from these 16 studies because it did not comply with the appraisal card criteria (attachment). The 15 studies included were controlled and randomized trials comparing open and closed systems for use in human adults.

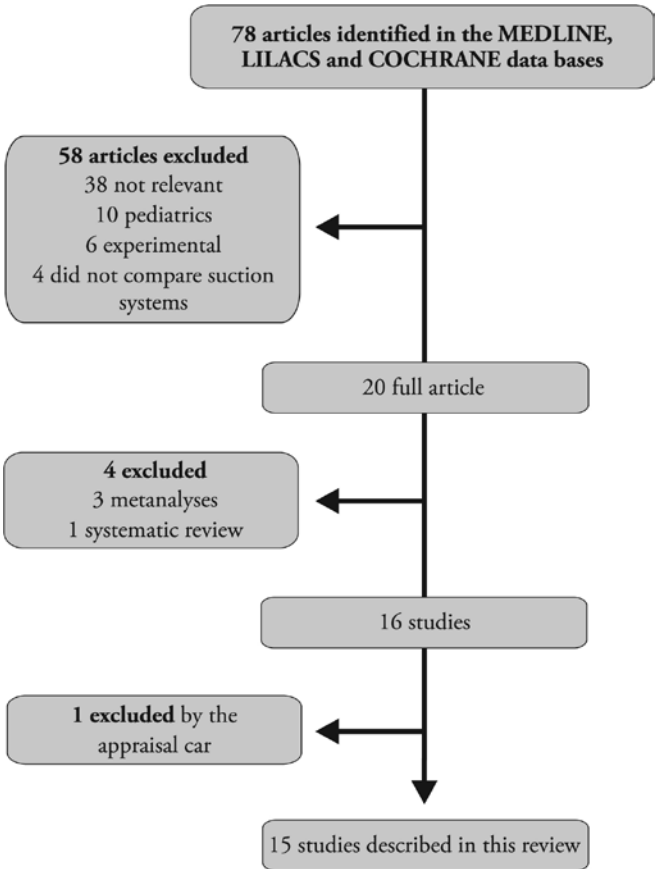

Figure 1 - Diagram showing the process for selection of studies.

Ventilator associated pneumonia

Nine articles were found comparing incidence of VAP, which was defined as presence of fever, appearance of a new or worse pulmonary infiltrate at chest X-ray and leukocytosis (≥ 10000/mm^3) and purulent tracheal secretion (Table 1). [2, 5, 6, 10, 15-19] The CSS induced a decrease of VAP in only two studies and in the remaining, no difference was found.

Mortality, intensive care length of stay and duration of mechanical ventilation

A study including 78 clinical and surgical patients was found, comparing mortality among patients suctioned using OSS and CSS, which did not disclose any statistically significant differences.[16]

Two studies compared ICU length of stay[16,18] and two compared duration of MV[16,19] in which no significant differences were found. Table 2 shows the profile of the studies.

Blood gas exchange variables (oxygen and carbon dioxide arterial pressure)

Only two studies related changes in oxygen arterial pressure (PaO_2) during the suction procedure;[14,20], whereas one of them also cites carbon dioxide arterial pressure ($PaCO_2$).[14] In the study by Lasocki et al, there was an 18% reduction of PaO_2 also an 8% increase of $PaCO_2$ and these changes continued after 15 minutes of the procedure.[14] When compared to what occurred with the CSS, the difference was statistically significant ($p< 0.05$).

Bourgault et al. in their study observed maintenance of the PaO_2 of 80 mmHg during suction with the CSS, as well as with the OSS, measured 30s and 5min after suction. [20] The two studies recommended hyperoxygenation with 100% of FiO_2 prior to aspiration with the OSS (Table 3).

Hemodynamic variables (peripheral oxygen saturation, mean arterial pressure and heart rate)

Six studies were found that compared changes in peripheral oxygen saturation (SpO_2) during the suction procedure with OSS and CSS. [5, 15, 21-24] In five there was a significant decrease of SpO_2 during the suction procedure with OSS. In the other there was no statistically

Table 1 – Studies found comparing the open and closed suction systems in relation to incidence of pneumonia

Studies	N	Categories	Results
Lorente et al.[2]	443	Clinical-surgical	No difference
Rabitsch et al.[5]	24	Clinical-surgical	CSS ↓ incidence of VAP↓
Adams et al.[6]	20	Liver transplant	No difference
Zeitoun et al.[10]	20	Clinical-surgical	No difference
Lee et al.[15]	70	Clinical-surgical	CSS ↓ incidence of VAP↓
Topeli et al.[16]	78	Clinical-surgical	No difference
Zeitoun et al.[17]	47	Clinical-surgical	No difference
Combes et al.[18]	104	Neurosurgical	No difference
Lorente et al.[19]	457	Clinical-surgical	No difference

N – number; CSS – closed suction system; VAP – ventilator associated pneumonia; MV – mechanical ventilation

Table 2 – Studies found comparing the open suction system to the closed suction system for mortality, length of stay in intensive care unit and time of mechanical ventilation

Studies	N	Categories	Results	Variables
Topeli et al.[16]	78	Clinical-surgical	No difference	Mortality and length of stay in ICU
Combes et al.[18]	104	Neurosurgical	No difference	Length of stay in ICU
Lorente et al.[19]	457	Clinical-surgical	No difference	Time of MV

N – number; ICU – intensive care unit; MV – mechanical ventilation

Table 3 – Studies found related to changes in oxygen and carbon dioxide arterial pressure

Studies	N	Categories	Results
Lasocki et al.[14]	18	Acute pulmonary injury	↓PaO_2 and ↑$PaCO_2$ with OSS
Bourgault et al.[20]	18	Clinical – surgical	Not significant decrease of PaO_2

N – number; OSS – open suction system; PaO2 – partial oxygen pressure; $PaCO_2$ – partial pressure of carbon dioxide

significant difference of SpO_2 between the two systems, with hyperoxygenation at 100% of FiO_2 before aspiration, as well as without this procedure.[21] In the first five studies hyperoxygenation is recommended before suction to avoid excessive decrease of SpO_2 (Table 4).

In four studies the variables considered were mean arterial pressure (MAP) and heart rate (HR)[20-23]. In two of these studies, no important differences were found when comparing the OSS and the CSS. [20, 21]

In the article by Cereda et al., suction with OSS brought about a significant increase of the MAP and maintenance of the HR, that continued 2 minutes after the procedure.[22] Another study reported increase of HR and MAP with the OSS and, furthermore, cited a statistically higher incidence of dysrhytmias (Table 5). [23]

Pulmonary volume

Three studies compared changes in pulmonary volume during suction with OSS and CSS**.** [21, 22, 24] In all plethysmography was used to measure expiratory pulmonary volume before and after the procedure. A statistically higher reduction of the pulmonary volume was found when OSS was used. This is justified because of disconnection of the patient from the mechanical ventilator as well as by the presence of a negative pressure caused by aspirator vacuum (Table 6).

Removal of secretion

Two studies compared the quantity of suctioned secretion with the OSS and the CSS. A larger mass of secretion suctioned with the OSS was reported in the first. [14] This article further compared the suction for two different intensities of negative pressure (- 200 and --400 cmH_2O). When the more negative pressure was used (-400 cmH_2O) more secretion was removed. Another study did not find differences in the volume of suctioned secretion between the two suction systems (Table 7).[18]

Costs

Four studies comparing costs between use of the OSS and the CSS were found. In the first two, cost of using CSS was higher than that of OSS.[2, 6] In the third study[15] cost of using CSS was lower and in the fourth,[19]

Table 4 – Studies found comparing peripheral oxygen saturation between the open and closed suction systems

Studies	N	Categories	Results
Rabbits et al.[5]	24	Clinical- surgical	Decrease of SpO_2 with OSS
Lee et al.[15]	14	Clinical- surgical	Decrease of SpO_2 with OSS
Maggiore et al.[24]	9	Clinical- surgical	Decrease of SpO_2 with OSS
Creedal et al.[22]	10	Clinical- surgical	Decrease of SpO_2 with OSS
Lee et al.[23]	14	Clinical- surgical	Decrease of SpO_2 with OSS
Fernandez et al.[21]	10	Clinical- surgical	No statistical difference

N – number; OSS – open suction system; SpO_2 – peripheral oxygen saturation

Table 5 – Studies citing changes in mean arterial pressure and heart rate between the open and closed suction systems

Studies	N	Categories	Results
Bourgault et al.[20]	18	Clinical- surgical	No difference
Fernández et al.[21]	10	Clinical- surgical	No difference
Cereda et al.[22]	10	Clinical- surgical	OSS: ↑ MAP and keeps HR
Lee et al.[23]	14	Clinical- surgical	OSS: ↑ HR and MAP

N – number; OSS – open suction system; MAP – mean arterial pressure; HR – heart rate

Table 6 – Studies relating pulmonary volume changes during suction with the open and closed suction systems

Studies	N	Categories	Results
Fernández et al.[21]	10	Clinical-surgical	OSS: Decrease of pulmonary volume
Cereda et al.[22]	10	Clinical-surgical	OSS: Decrease of pulmonary volume
Maggiore et al.[24]	23	Clinical-surgical	OSS: Decrease of pulmonary volume

N – number; OSS – open suction system

Table 7 – Studies found comparing the quantity of secretion suctioned with the open and closed suction systems

Studies	N	Categories	Results
Lasocki et al.[14]	18	Acute pulmonary injury	OSS: greater mass of suctioned secretion
Combes et al.[18]	104	Neurosurgical	No difference

N – number; OSS- open suction system

Table 8 – Studies comparing costs between use of the closed and open suction systems

Studies	N	Categories	Results
Lorente et al.[2]	443	Clinical-surgical	CSS with higher cost
Adams et al.[6]	20	Liver transplant	CSS with higher cost
Lee et al.[15]	70	Clinical-surgical	CSS with higher cost
Lorente et al.[19]	457	Clinical-surgical	CSS with higher cost if used for less than 4 days.

N- number; CSS- closed suction system

the cost of CSS was higher when used for less than 4 days. It should be noted that in this last work, costs of OSS and CSS were compared without a daily change of the closed system. (Table 8)

DISCUSSION

During the development of this study difficulties for comparison of studies were found, because there were many discrepancies between methods. Furthermore, the populations studied were quite heterogeneous.

In relation to MAP, seven of the nine studies did not disclose differences between both systems. In 2 other studies [5, 15] there was a decrease of MAP with CSS, and Rabitsch et al. [5] also found less cross contamination between gastric juice and tracheal secretion.

In their study Topeli et al.[16] reported that even though there were no significant differences between the two suction systems, appearance of multiresistant bacteria such as *Acinetobacter spp* and *Pseudomonas aeruginosa* was more common in the CSS.

Adams et al.[6] also reported that there was no significant difference regarding incidence of VAP, however stressing that with the CSS more suctions are performed because of the procedure's ease and a lesser efficacy of the method, according to reports of the team.

In the study by Lorente et al. [19] the OSS and CSS were compared, however without a daily change of the closed circuit, as recommended by the manufacturer. The outcome was that there was no increased incidence of VAP as long as it is used for no more than 4 days.

Five of the six studies showed a decrease of SpO_2 when the OSS was utilized. This result leads to a belief that in patients who may be severely affected by short periods of hypoxemia, such as those hemodynamically unstable, CSS should be preferred. It must be emphasized that the data collection moment varied from study to study (ranging from immediately after and up to 2 minutes after suction) and that may have interfered in the results. This because, if in all work, collection had been made 5 minutes after suction, it is possible that saturation would have already returned to its initial values.

Likewise, pulmonary volumes presented a decrease in the three studies found, however measurement was also made at different moments, ranging from prior to suction to immediately afterwards and before suction to 10 minutes after the procedures. In the latter, pulmonary volume had already returned to the initial state. [21]

Among the fours studies comparing costs between both systems, two inferred that the CSS has a higher cost,[2,6] one that it has a lower cost [15] and another that it has a higher cost if the same equipment is used for less than four days.[19] It should be remembered that when the CSS is used, the common suction probe must also be used to aspirate the nose and mouth to reduce incidence of ventilator associated pneumonia. And when suction is performed the traditional way, the same probe is used for the tracheal tube, nose and mouth, in this order.

Therefore in CSS the same material is used in the OSS, in addition to the closed system itself. In the universe of intensive care some of the most important outcomes are: decrease of mortality, length of stay in ICU and time of mechanical ventilation. In

the studies found there was no difference in any of these items, disclosing that one as well as the other may be used.

These results are congruent with those of three meta-analyses found on the subject.[8,25,26]

Jorgenden et al.[8] analysed mortality, cardiopulmonary variables, bacterial contamination, secretion volume and costs; Peter et al.[25] compared ventilator associated pneumonia and mortality and in Vonberg et al.[26], only pneumonia. None was able to conclude anything about superiority of one of those methods.

No sufficient scientific evidence was found to prepare a flowchart with guidelines for the choice of one or the other systems, as proposed in the objective of this work.

CONCLUSION

Based upon the systematic review carried out, it was concluded that there is no difference regarding the compared variables: incidence of VAP, mortality, length of stay at ICU, time of MV, $PaCO_2$, PaO_2, MAP and HR and removal of secretion when using OSS and CSS. However, there was always a decrease of SpO_2 and of pulmonary volumes with use of the OSS; and higher costs in the majority of studies with the use of the CSS.

As such, CSS seems to increase the risk of colonization, but has the advantage of not reducing the pulmonary volumes and not entailing a drop of saturation, especially in patients with severe respiratory failure and in the use of higher levels of positive end expiratory pressure. New studies on the subject are suggested in an effort to prepare the flowchart initially proposed.

RESUMO

Objetivos: Este estudo foi realizado para tentar esclarecer qual sistema de aspiração é mais eficiente. O objetivo foi comparar os sistemas fechado e aberto de aspiração através de revisão sistemática.

Métodos: A busca de artigos científicos foi realizada nas bases de dados MedLine, LILACS e Cochrane abrangendo o período entre 1997 e agosto de 2007 utilizando as palavras-chave: *endotracheal suction* e *closed suction.* Foram incluídos os estudos que compararam o sistema aberto e fechado de aspiração, realizados em adultos humanos e que eram ensaios aleatórios e controlados.

Resultados: Dos 78 artigos encontrados apenas 15 preencheram os critérios e foram detalhados na revisão. Dentre estes, nove artigos comparavam a incidência de pneumonia associada à ventilação mecânica entre os dois sistemas, seis comparavam a saturação de oxigênio, quatro comparavam pressão arterial e freqüência cardíaca, três comparavam volumes pulmonares, dois comparavam remoção de secreção e quatro; custos. Não houve diferença em relação às variáveis comparadas: incidência de pneumonia associada à ventilação mecânica, mortalidade, tempo de unidade de terapia intensiva, tempo de ventilação mecânica, $PaCO_2$, PaO_2, pressão arterial média, freqüência cardíaca e remoção de secreção no uso do sistema aberto e fechado de aspiração. Porém, houve sempre diminuição de SpO_2 e dos volumes pulmonares com o uso do sistema aberto; e custos maiores na maioria dos trabalhos quando utilizado o sistema fechado.

Conclusões: O sistema fechado de aspiração parece aumentar o risco de colonização, mas traz as vantagens de não diminuir os volumes pulmonares e não acarretar queda de saturação especialmente em pacientes com insuficiência respiratória grave e em uso de níveis mais altos de pressão expiratória final positiva.

Descritores: Pneumonia associada à ventilação mecânica; Análise custo-benefício; Sucção/economia; Sucção/métodos; Respiradores mecânicos/economia

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APPENDIX

Appraisal card of the scientific study method for systematic review

Appraiser:_____ Date: _____

Level of evidence:_____

I) Study title			
Suitable for the subject	( ) Yes	( ) No	
Close to the research objective	( ) Yes	( ) No	
II) Introduction:			
Places the reader to the subject	( ) Yes	( ) No	
History of the subject	( ) Yes	( ) No	
Definition and concept	( ) Yes	( ) No	
Pertinent literature and Yesilar	( ) Yes	( ) No	
Justification for research	( ) Yes	( ) No	
III) Objective:			
Correctly formulated hypothesis	( ) Yes	( ) No	
Clear and concise	( ) Yes	( ) No	
IV) Scientific method:			
Adequate description of type/design	( ) Yes	( ) No	( ) Not applicable
Adequate casuistry	( ) Yes	( ) No	( ) Not applicable
Sample characteristics	( ) Yes	( ) No	( ) Not applicable
Number of subjects	( ) Yes	( ) No	( ) Not applicable
Control group	( ) Yes	( ) No	( ) Not applicable
Adequate randomization	( ) Yes	( ) No	( ) Not applicable
Adequate inclusion criteria	( ) Yes	( ) No	( ) Not applicable
Adequate exclusion criteria	( ) Yes	( ) No	( ) Not applicable
Description of adequate material	( ) Yes	( ) No	( ) Not applicable
Description of procedures	( ) Yes	( ) No	( ) Not applicable
Statistical analysis	( ) Yes	( ) No	( ) Not applicable
V) Adequate results:	**(**) Yes	( ) No	
VI) Adequate bibliographic references:	( ) Yes	( ) No	
Provides new reference that can be included in this systematic review:	( ) Yes	( ) No	

APPROVED: ( ) Yes ( ) No