Original Article

RANDOMIZED COMPARATIVE ANALYSIS BETWEEN TWO TRACHEAL SUCTION SYSTEMS IN NEONATES

Lúcia Cândida Soares de Paula[1*], Maria Esther Jurfest Ceccon[2]

Study conducted at the Neonatal Intensive Care Unit (NICU) of the Children's Institute of Hospital das Clínicas, School of Medicine, Universidade de São Paulo, São Paulo, SP, Brazil

ABSTRACT

Objective. To quantify and compare variations in oxygen saturation throughout the suctioning procedure (before, during, and after) using two endotracheal suction systems: open suction system (OSS) vs. closed suction system (CSS).

Methods. A prospective randomized controlled study was carried out with 39 newborn infants of gestational age ≥ 34 weeks using pressure-limited, time-cycled, continuous-flow mechanical ventilators. The infants were classified into two groups according to ventilatory parameters: Group I was ventilated using positive end-expiratory pressure (PEEP) ≥ 5 cm H_2O and mean airway pressure (MAP) ≥ 8 cm H_2O; and Group II using PEEP < 5 cm H2O and MAP < 8 cm H_2O.

Results. No statistically significant differences were observed when OSS and CSS were compared in both groups. There was a statistically significant improvement in post-procedure oxygen saturation in both groups.

Conclusion. Both endotracheal suction systems can be used with no drawbacks of OSS in relation to CSS, provided the sample is similar to that of the present study.

Key words: Suction. Oximetry. Physical Therapy (Specialty). Infant, Newborn. Respiration, Artificial.

***Correspondence:**
Rua Embaú, 206 – apto.13
Vila Clementino
São Paulo – SP, Brazil
CEP: 04039-060

Introduction

The increased survival of high-risk neonates in recent decades is the result of technological and scientific development in perinatal and neonatal medicine and improvements mainly in respiratory care, with microprocessor-based mechanical ventilators and monitoring equipment appropriate for the neonatal period[1].

Ventilatory support may be administered in a noninvasive and invasive manner, and both are important resources in the treatment of infants admitted to the neonatal intensive care unit (NICU). However, especially invasive support, which is the subject of our study, may be associated with some complications[2-4].

There is great variation in physical therapy techniques used in neonates, and among them we report endotracheal suction. Endotracheal suctioning can be performed through two systems described below.

The conventional or open suction system requires the opening of the breathing circuit through the disconnection of the endotracheal tube from the mechanical ventilator and insertion of a suction catheter of appropriate size for the diameter of the endotracheal tube.

The closed suction system was developed in the late 1980s and employs a multiple-use suction catheter that is attached to the ventilator circuit, with no need to disconnect it from the patient to perform suction[5].

The main objective of endotracheal suctioning is to remove secretions, preventing airway obstruction, atelectasis, and pulmonary infections.6 Although it is recognized that endotracheal suction is essential for patients, its use may produce some adverse effects, such as: decreased oxygenation, changes in heart rate, microatelectasis, bronchoconstriction, increased intracranial pressure, infection, trauma to the tracheobronchial mucosa, pneumothorax, apnea, and even cases of death. Death cases have been reported in studies conducted with adult patients[7-12].

Two endotracheal suction systems are commercially available: the open endotracheal suction system (OSS) and the closed endotracheal suction system (CSS). The objective of this study was to compare variations in oxygen saturation throughout the suctioning procedure (before, during, and after) using the two available suction systems.

1. Mestre em Pediatria pela Faculdade de Medicina da Universidade de São Paulo – FMUSP e Fisioterapeuta responsável da Unidade de Cuidados Intensivos Neonatal (UCINE) do Instituto da Criança do HC -FMUSP, São Paulo, SP
2. Livre-docente em Pediatria pela Faculdade de Medicina da Universidade de São Paulo - FMUSP e Médica chefe da Unidade de Cuidados Intensivos Neonatal (UCINE) do Instituto da Criança do HC-FMUSP, São Paulo, SP

Methods

The study was approved by the Research Ethics Committee of Universidade de São Paulo (USP), Brazil, and all parents/legal guardians provided written informed consent. A randomized clinical trial was performed with 39 newborn infants admitted to the NICU at the Children's Institute of USP Hospital das Clínicas. Infants who had cardiac malformations confirmed by echocardiography, tension pneumothorax requiring drainage or not, extensive atelectasis affecting at least one lobe, inhaled nitric oxide (NO), or received high-frequency ventilation were excluded from the study.

The 39 infants studied were classified into two groups according to the need for lower or higher ventilatory parameters, as described below, in order to verify whether the lungs subjected to different inspired oxygen fractions and mean airway pressures would behave differently during and after the suctioning procedure.

Group I – Infants who required the following ventilatory parameters: fraction of inspired oxygen (FIO2) ≥ 50%; positive inspiratory pressure (PIP) ≥ 20 cm; positive end-expiratory pressure (PEEP) ≥ 5; respiratory rate (RR) ≥ 30 bpm; flow ≥ 6 L.

Group II – Infants who required the following ventilatory parameters: FIO2 < 50%; PIP < 20 cm; PEEP < 5; RR < 20 bpm; flow < 6 L.

Randomization was performed before each procedure by using cards identified as OSS and CSS, which were placed inside dark envelopes and randomly distributed to the draw.

OSS was performed according to the following criteria: decrease of saturation below 89%; respiratory distress; pulmonary auscultation; and patient restlessness. In all infants preductal oxygen saturation (SpO_2) was measured by pulse oximetry (right radial artery). Multiprogrammable neonatal monitors were used: V24E® (Phillips); Infinity vista XL® (Dräger); and Portal DX2020® (Dixtal). SpO_2 was measured at the following time points:

Ta- Before the infant was positioned for suctioning (time required to check the condition of the infant); **Tb**- IImmediately before suctioning (infant held in position); **Tc**- During all suctions, **Tc_1** - after the first suction, **Tc_2** - after the second suction; **Td**- Five minutes after the procedure; **Te**- Ten minutes after the procedure.

ABefore starting the suctioning procedure, the following care procedures were observed and followed:

1) Conditions for fixation of endotracheal tube: it was always kept patent.

2) The length of the tube for fixation after intubation was calculated from the Torchen rule[13] (1979), represented by the weight in kilograms[6]. Immediately after this procedure a radiologic examination was performed to confirm the position of the tip of the tube in the intervertebral space between the second and third thoracic vertebrae (T_2 and T_3) of the infant.

3) Humidification was maintained by constantly filling the humidifier with water, maintaining the power between 4 and 5 to reach an inspired gas temperature of 37° C, as recommended by the manufacturer Fisher Paykel.

5) The infants were positioned supine 10 minutes before care was started, with the head in the midline and neck in mild extension.

After initial care procedures: preductal SpO_2 of the infant was noted down; the infant was preoxygenated, with a 10% increase in previous FIO2; and after a three-minute interval the suctioning procedure was initiated. During suctioning no type of solution, such as saline and/or distilled water, was instilled. A suction catheter #6 or #8, according to the size of the endotracheal tube (2.5, 3.0, 3.5, and 4 cm) was inserted only twice during each procedure, and the time interval between insertions was three minutes. The negative pressure used during suctioning was 15 to 20 cmHg.

Statistical analysis was performed as follows: for qualitative variables absolute and relative frequency were calculated, and for quantitative variables median and minimum and maximum values were calculated. The association of both groups (Groups I and II) with each of the qualitative variables was performed using the chi-square test or Fisher's exact test, when the former was not suitable. The comparison between both groups and quantitative variables was performed using the Mann-Whitney test.

For the variables analyzed, in each of the suction systems, which had more than one measurement over time (SpO_2), the average profile was constructed with vertical bars representing the standard error. Repeated-measures analysis of variance (ANOVA) was used for the modeling of these variables, which allowed an adjustment taking into account a possible correlation of data collected.14,15 Based on this model, contrasts were constructed that allowed us to evaluate possible differences between both systems and to evaluate variations in these measurements during monitoring of each system studied. All statistical analyses were performed using SAS 9.1 for Windows. A significance level of 5% was adopted in all statistical analyses, i.e., results with $p < 0.05$ were considered as statistically significant.

Results

The two groups of infants were homogeneous in terms of sex, newborn classification, weight, and mode of mechanical ventilation ($p > 0.05$). However, in relation to mode of ventilation, there was a higher percentage of infants receiving intermittent mandatory ventilation (IMV) in Group II compared to the percentage observed in Group I, but the statistical difference was marginally significant ($p = 0.055$). Group I had a higher percentage of infants in use of vasoactive drugs and sedatives ($p < 0.05$). There was no significant difference between groups with respect to analgesia ($p = 0.182$) (Tables 1, 2, and 3).

Regarding the parameters studied in Group I, as seen in Table 4 and Figure 1, mean SpO_2 at time point **Ta** was higher in the OSS than in the CSS. A decrease in SpO_2 was then observed from **Tb** until **Tc_1** in both OSS and CSS. From **Tc_1** to **Tc_2**, both systems showed an increase in mean SpO_2. SpO_2 continued to rise from **Tc_2** to **Td** in both systems; however, mean SpO_2 in the CSS was apparently lower than that observed in the OSS. At time point Te, in both groups,

Table 1 - Characteristics of the sample included in a comparative study of closed suction system vs. open suction system in newborn infants receiving invasive conventional mechanical ventilation (n = 39)

	Group I (n=18)	Group II (n=21)	p
Sex			0.688
Female	10 (55.6%)	13 (61.9%)	
Male	8 (44.4%)	8 (38.1%)	
Newborn classification			0.215
Preterm	5 (27.8%)	2 (9.5%)	
Term	13 (72.2%)	19 (90.5%)	
Weight (g)			0.900
Median (Min - Max)	3150 (1540 - 4820)	2995 (2210 - 5400)	
MV mode			0.055
IMV	11 (61.1%)	19 (90.5%)	
SIMV	7 (38.9%)	2 (9.5%)	
Tube number			0.141
2.5	-	1 (4.8%)	
3.0	5 (27.8%)	11 (52.4%)	
3.5	12 (66.7%)	9 (42.9%)	
4.0	1 (5.6%)	-	
Tube fixation number			0.862
Median (Q1-Q3)	9.5 (9.0 - 10.0)	9.5 (9.5 - 10.0)	
Min - Max	8.0 - 12.0	8.0 - 12.0	

IMV = intermittent mandatory ventilation; SIMV = synchronized intermittent mandatory ventilation.

Table 2 - Diagnoses of the sample included in a comparative study of closed suction system vs. open suction system in newborn infants receiving invasive conventional mechanical ventilation (n = 39)

	Group I	Group II	p
Esophageal atresia	2 (11.1%)	5 (23.8%)	0.639
Omphalocele	2 (11.1%)	2 (9.5%)	
Gastroschisis	1 (5.6%)	4 (19.1%)	
Asphyxia	3 (16.7%)	2 (9.5%)	
Encephalocele	1 (5.6%)	1 (4.8%)	
MAS	1 (5.6%)	1 (4.8%)	
Sepsis	2 (11.1%)	3 (14.3%)	
Pneumonia	3 (16.7%)	0 (0.0%)	
Bronchiolitis	2 (11.1%)	1 (4.8%)	
Pertussis	1 (5.6%)	0 (0.0%)	

MAS = meconium aspiration syndrome .

Table 3 - Use of analgesics, sedatives, and vasoactive drugs in the sample included in a comparative study of closed suction system vs. open suction system in newborn infants receiving invasive conventional mechanical ventilation (n = 39)

	Group I (n=18)	Group II (n=21)	p
Sedation	12 (66.7%)	6 (28.6%)	0.017
Sedative drugs			-
Midazolam	12 (100.0%)	6 (100.0%)	
Analgesia	11 (61.1%)	7 (38.9%)	0.182
Analgesic drugs			0.137
Dipyrone	-	1 (14.3%)	
Fentanyl	11 (100.0%)	5 (71.4%)	
Fentanyl + Dipyrone	-	1 (14.3%)	

SpO_2 was similar to that observed in the previous time point, and the difference in mean SpO_2 between systems remained the same. Despite the difference described by repeated-measures ANOVA, the interaction between system and time produced no statistically significant effect, i.e., both systems showed the same SpO_2 behavior over time and there was a statistically significant increase in SpO_2 in both systems from time point **Ta** to **Te**, demonstrating effectiveness of the procedure.

Regarding SpO_2 in Group II, as described in Table 5 and Figure 2, both systems showed SpO_2 profiles with the same behavior over time, with OSS showing higher mean SpO_2 than CSS throughout the monitoring period.

Repeated-measures ANOVA revealed that both systems showed the same SpO_2 behavior throughout the evaluation period ($p = 0.964$). There was no statistically significant difference in mean SpO_2 between systems ($p > 0.05$). Time had a statistically significant effect on both systems evaluated ($p < 0.05$).

Discussion

The literature reports possible advantages and disadvantages of each suction system. CSS, for example, is believed to induce fewer episodes of hypoxia and its consequences; however, suction catheters used in CSS are more expensive than those used in OSS and are not available in all health care facilities[16-18].

In our research, infants in both groups (I and II) showed no statistically significant differences in relation to weight (mean of 3,150 g in Group I and 2,995 g in Group II), sex (10 female infants in Group I and 13 in Group II; 8 male infants in Group I and 8 in Group II), and newborn classification (5 preterm infants in Group I and 2 in Group II; 13 term infants in Group I and 19 in Group II). Therefore, our sample was considered a homogeneous group suitable for comparison. Gestational age greater than 34 weeks was chosen because infants of gestational age less than 34 weeks have immature neurological and cardiorespiratory

Table 4 - Mean ± standard deviation of oxygen saturation, according to system and time, in a comparative study of closed suction system vs. open suction system in newborn infants receiving invasive conventional mechanical ventilation (Group I)

	System		
Evaluation time point	Open suction	Closed suction	p
Ta	95.6 ± 2.7	94.6 ± 3.5	0.185
Tb	95.7 ± 2.7	94.1 ± 4.0	0.155
Tc1	93.7 ± 3.7	93.3 ± 4.7	0.745
Tc2	94.1 ± 3.5	94.0 ± 3.4	0.863
Td	96.8 ± 2.3	96.1 ± 3.3	0.236
Te	96.7 ± 2.5	95.9 ± 3.6	0.190
p	0.003	<0.001	

Table 5 - Mean ± standard deviation of oxygen saturation, according to system and time, in a comparative study of closed suction system vs. open suction system in newborn infants receiving invasive conventional mechanical ventilation (Group II)

	System		
Evaluation time point	Open suction	Closed suction	p
Ta	97.0 ± 1.8	96.3 ± 2.1	0.226
Tb	97.2 ± 2.1	96.4 ± 2.0	0.151
Tc1	96.0 ± 2.9	95.6 ± 2.4	0.432
Tc2	96.6 ± 2.5	95.9 ± 2.5	0.237
Td	97.4 ± 2.0	97.0 ± 1.7	0.289
Te	97.7 ± 1.6	97.3 ± 1.6	0.296
p	0.046	0.006	

Figure 1 - Mean ± standard error of oxygen saturation (SpO_2), according to system and time, in a comparative study of closed suction system vs. open suction system in newborn infants receiving invasive conventional mechanical ventilation (Group I)

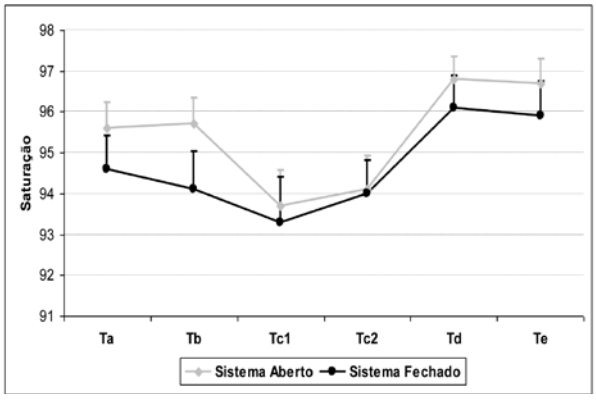
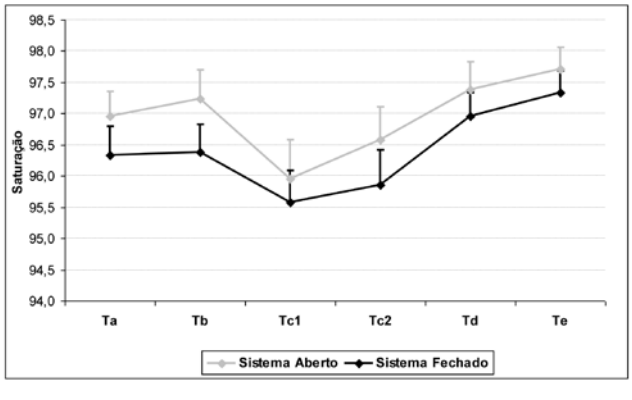


Figure 2 - Mean ± standard error of oxygen saturation (SpO_2), according to system and time, in a comparative study of closed suction system vs. open suction system in newborn infants receiving invasive conventional mechanical ventilation (Group II)



systems, which could lead to alterations inherent in prematurity.

Diagnoses were diverse, including: respiratory problems, such as pneumonia, bronchiolitis, and pertussis; surgical problems, such as esophageal atresia, omphalocele, gastroschisis, and myelomeningocele; and neurological conditions, such as perinatal asphyxia.

Midazolam was used for sedation, and dipyrone, fentanyl, or a combination of both drugs was used for analgesia. A statistically significant difference was observed between groups regarding sedation and analgesia, being higher in Group I, as shown in Table 3. This difference is due to the fact that this group was composed of infants requiring increased ventilatory support.

Intubation and mechanical ventilation are major causes of pain and stress in neonates. Mechanical ventilation and related invasive procedures are associated with several biochemical, physiologic, and behavioral alterations, indicating that pain and stress in neonates may lead to clinical instability and an adverse clinical prognosis. In ventilated infants, pain may lead to restlessness and asynchrony between ventilation and spontaneous breathing, resulting in inadequate ventilation. Endotracheal suction is one of these invasive procedures; however, thus far there is no evidence that the use of drugs and non-pharmacological therapy can minimize pain during the procedure.19-20 An important finding in our study is that the sedative doses used allowed spontaneous breathing of the infant, which is an important aspect, since the decrease in spontaneous breathing can lead to larger lung volume loss during suctioning and hinder the recruitment of this volume[21].

The care observed during the suctioning procedure derives from the existing data mentioned above and from the experience of the physical therapy team of the NICU, which performs all physical therapy treatments and is present over 24 hours every day. We described in detail the standardization of the procedure aiming to show that the results obtained may be due to the type of method used, which can be reproduced in other health care facilities.

Infants included in this study were classified into two groups according to ventilatory support. The most relevant parameters were PEEP and mean airway pressure (MAP), which maintain alveolar recruitment and oxygenation, respectively. Group I was ventilated using PEEP $\geq$ 5 cm H_2O and MAP $\geq$ 8 cm H_2O, and Group II using PEEP $<$ 5 cm H_2O and MAP $<$ 8 cm H_2O.

A major concern in relation to endotracheal suction is lung volume loss, which can promote alveolar collapse and, thus, the need to reopen the lung units, which in turn may cause acute lung injury. Arterial oxygenation coincides with changes in lung volume[21].

Studies by Maggiore et al. (2003)[21], Cereda *et al.*[22] (2001); and Lasocki et al[23]. (2006) in adult patients with acute lung injury showed decreased lung volume and decreased arterial oxygenation after the use of OSS. Choong et al.[24] (2003) corroborate the previous data in a study of children aged between 6 days and 13 years in which OSS and CSS were compared. Those authors showed that total lung volume loss was significantly greater with OSS and children suctioned with this system desaturated to a greater extent; thus, they suggested that CSS should be used in pediatric patients, especially those with significant lung disease, who require high PEEP, to avoid alveolar derecruitment and hypoxia during suctioning.

However, a more recent study by Hoellering et al.[25] (2008) with 30 neonates, 20 receiving synchronized intermittent mandatory ventilation (SIMV) and 10 high-frequency oscillatory ventilation (four of these receiving muscle relaxant), in which OSS and CSS were performed in a random order, using same size catheters, same value for negative pressure, and same duration for both procedures, showed that both systems produced a transient reduction in heart rate and SpO_2. Those same authors reported that lung volume loss was not affected by the type of system, as well as regaining lung volume was not influenced when patients were receiving SIMV. However, time to regain lung volume was longer with OSS than CSS, when patients were receiving high-frequency ventilation.

Regarding the results of our population, comparisons at six predetermined time points showed no statistically significant differences in SpO_2 between the two systems in both groups (Table 1/Figure 1, Table 2/Figure 2). In both systems SpO_2 showed a decrease during the suctioning procedure at time points Tc_1 and Tc_2, although this fall was not clinically significant. Mean values remained within the SpO_2 limits recommended for neonates, which is 89-95%[26].We believe that the main strategy to prevent and/or minimize hypoxemia induced by endotracheal suction is to limit the procedure time to 15 seconds and preoxygenation to only 10% above the initial FIO2, approaches observed in this study. Other strategies, such as hyperventilation and hyperinsufflation, should be avoided in this population.

A study by Heinze et al[27]. (2008) analyzed changes in functional residual capacity of 20 postoperative cardiac surgery adult patients after suctioning with OSS and CSS in different ventilatory modes. The study showed a decrease in functional residual capacity after suctioning, regardless of the system used. Similar to our study, SpO_2 recovered rapidly after suctioning, regardless of the suction system or ventilatory mode used.

The ability to maintain spontaneous breathing during ventilation so that patients can recruit their own lung volume may be more important than the suctioning method used. The effect of endotracheal suction on lung volume may depend on the ventilatory mode and settings, the suctioning technique and duration, as well as on the ratio between the diameters of the endotracheal tube and the suction catheter[21,27].

Therefore, this study provided us with evidence of safety to continue using OSS, which is the most widely used in NICUs, since there were no statistically significant differences in oxygenation. Nevertheless, we point out that patients with more severe lung disease than that observed in our sample, such as patients with diaphragmatic hernia associated with persistent pulmonary hypertension of the newborn, might benefit more from the use of CSS than OSS,

as long as the care procedures mentioned in this study are observed.

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