

Effects of suppression of endotracheal suctioning in the incidence of pulmonary complications on the postoperative cardiac surgery

Efeitos da supressão da aspiração endotraqueal na incidência de complicações pulmonares no pós-operatório de cirurgia cardíaca

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ABSTRACT | INTRODUCTION: Endotracheal suction is routinely used after cardiac surgery to ensure adequate ventilation. **OBJECTIVE:** To verify if that the absence of endotracheal suctioning before extubation in patients without signs of bronchial secretion have influence on the incidence of pulmonary complications, beyond hemodynamic and ventilatory repercussions of the procedure and costs. **METHODS:** Patients were evaluated between August/2012 and July/2014, divided equally into ASP Group (tracheal aspiration prior to extubation) and NASP (without prior aspiration). Individuals with: first cardiac surgery, age between 18 and 75 years, BMI ≤ 30 kg / m² and without previous lung disease were included. Individuals with ECC time > 120 minutes, need for mechanical circulatory assistance, PaO₂ / FiO₂ ratio <200, SpO₂ <92%, intubation time > 12 hours, MBP <60 mmHg and signs of pulmonary secretion were excluded. Hemodynamic, ventilatory variables, pulmonary complications and hospital costs were assessed. **RESULTS:** 228 patients were analyzed (ASP = 114 NASP = 114). HR, SBP, DBP and MBP increased after aspiration and post extubation in the groups, returning to baseline values over time. There was no statistical difference in RR and SpO₂. Pulmonary complications accounted for 7.8%, with no difference between groups. **CONCLUSION:** The suppression of tracheal suctioning in patients in the immediate postoperative period of cardiac surgery did not influence the incidence of pulmonary complications and postoperative clinical evolution. During aspiration, there were hemodynamic and respiratory changes, with no clinical repercussions, but these same changes occurred in the NASP group after extubation, to a lesser extent. Endotracheal suctioning without indication proved to be costly and wasted professionals' time.

KEYWORDS: Suction. Pulmonary atelectasis. Thoracic surgery. Health care costs. Physiotherapy.

RESUMO | INTRODUÇÃO: Aspiração traqueal é utilizada rotineiramente após cirurgia cardíaca para garantir adequada ventilação. **OBJETIVO:** Verificar se a ausência da aspiração traqueal antes da extubação em pacientes sem sinais de secreção brônquica influencia na incidência de complicações pulmonares, além de repercussões hemodinâmicas e ventilatórias do procedimento e custos. **MÉTODOS:** Pacientes foram avaliados entre agosto/2012 e julho/2014, divididos igualmente em Grupo ASP (aspiração traqueal prévia à extubação) e NASP (sem aspiração prévia). Foram incluídos indivíduos com: primeira cirurgia cardíaca, idade entre 18 e 75 anos, IMC ≤ 30 kg/m² e sem doença pulmonar prévia. Foram excluídos indivíduos com tempo de CEC > 120 minutos, necessidade de assistência circulatória mecânica, relação PaO₂/FIO₂ < 200, SpO₂ < 92%, tempo de intubação > 12 horas, PAM < 60 mmHg e sinais de secreção pulmonar. Variáveis hemodinâmicas, ventilatórias, complicações pulmonares e custos hospitalares foram avaliados. **RESULTADOS:** Foram analisados 228 pacientes (ASP= 114 NASP= 114). FC, PAS, PAD e PAM elevaram-se após aspiração e pós extubação nos grupos, retornando aos valores basais no decorrer do tempo. Não houve diferença estatística na FR e SpO₂. Complicações pulmonares representaram 7,8%, sem diferença entre os grupos. **CONCLUSÃO:** A supressão da aspiração traqueal nos pacientes em pós-operatório imediato de cirurgia cardíaca não influenciou na incidência de complicações pulmonares e evolução clínica pós-operatória. Durante aspiração, houve alterações hemodinâmicas e respiratórias, sem repercussões clínicas, porém estas mesmas alterações ocorreram no grupo NASP após extubação, em menor intensidade. Aspiração endotraqueal sem indicação mostrou-se custosa e com desperdício de tempo dos profissionais.

PALAVRAS-CHAVE: Aspiração traqueal. Cirurgia cardiovascular. Complicações pulmonares. Fisioterapia.

Endotracheal intubation is commonly used in cardiac surgery to ensure adequate ventilation and monitoring. Nevertheless, it prevents effective mobilization and removal of bronchial secretions¹. Endotracheal suctioning of bronchial secretions in patients, who have been intubated, is applied to ensure airway patency² and prevent pulmonary complications^{3,4}.

This procedure routine is highly applicable but may cause undesirable effects such as decreased dynamic compliance and functional residual capacity, atelectasis, hypoxemia, tissue trauma to the tracheal and/or bronchial mucosa, bronchospasm, cardiovascular instability and cardiac arrhythmias, pain and anxiety⁵⁻⁷.

These complications may be accentuated in post-cardiac surgery patients due of hemodynamic changes caused by the surgical procedure. Moreover, these complications may be associated with previous pre and postoperative clinical conditions.

Therefore, endotracheal suctioning should be indicated only in specific cases. The presence of bronchial secretions can be detected by auscultation of lung sounds such as coarse crackles, visible secretions in the orotracheal tube, sawtooth pattern on the flow-volume loop, and increased peak inspiratory pressure during volume-controlled mechanical ventilation.

However, in the immediate postoperative period, patients are routinely subjected to endotracheal and nasotracheal suctioning before extubation, despite a brief time of mechanical ventilation and no signs of bronchial secretion retention.

To verify our hypothesis that the absence of endotracheal suctioning before extubation in patients without signs of bronchial secretion doesn't influence on the incidence of pulmonary complications, we proposed this study which performed in the immediate postoperative period of cardiac surgery. We also evaluated the hemodynamic and ventilatory repercussions of the procedure involving extubation and costs.

Participants

This prospective, observational, randomized study was conducted between August 2012 and July 2014 in the surgical intensive care units (ICUs) of the Heart Institute of the Hospital das Clínicas, Medical School, University of São Paulo. The intervention protocol received ethical clearance under CAAE number 11855413.3.0000.0068. The study sample comprised 228 subjects, who were equally randomized into two groups: the ES group (endotracheal suctioning, i.e., extubation with previous endotracheal and nasotracheal suctioning) and the NES group (non endotracheal suctioning, i.e., extubation without previous tracheal and nasotracheal aspiration).

Only patients subjected to a first heart surgery were eligible for the study. The inclusion criteria were: age of 18–75 years, body mass index (BMI) ≤ 30 kg/m², and absence of previous pulmonary disease. Subjects were excluded in cases of cardiopulmonary bypass time > 120 min, the need for mechanical circulatory assistance, PaO₂/FiO₂ < 200 , peripheral oxygen saturation (SpO₂) $< 92\%$, intubation time > 12 hours, and mean blood pressure (MBP) < 60 mmHg. The patients with bronchial secretion, characterized by a sawtooth pattern on the flow-volume loop, secretion in the endotracheal cannula, or coarse crackles sounds, were also excluded.

Protocol

The subjects who fulfilled the study criteria were included at the time of admission to the surgical ICU. They were intubated and ventilated with parameters adjusted to ensure SpO₂ $\geq 95\%$.

In the absence of respiratory, metabolic, hemodynamic, or neurological alterations, a ventilatory support withdrawal program was implemented gradually. At the pre-extubation moment, the subjects were randomized into two groups:

- ES group. In the recumbent position, FiO₂ was increased to 1.0 for 1 min, and SpO₂ was monitored. Subsequently tracheal aspiration was performed and the patient was reconnected to the ventilator until normalization of SpO₂. After that, nasotracheal aspiration was performed, followed by oral aspiration. During maximal inspiration, the cuff was deflated, and the endotracheal tube

was removed. Subsequently, a nasal oxygen catheter was installed, with an oxygen flow rate of 5 L/min to maintain the SpO₂ equal or higher than 95%.

- NES group. In the recumbent position, the mechanical ventilator was disconnected, the cuff was deflated, the patient was asked to inhale at maximal capacity, and the endotracheal tube was removed. Subsequently, a nasal oxygen catheter was installed, with an oxygen flow rate of 5 L/min to maintain the SpO₂ equal or higher than 95%.

The length the procedure was calculated for both groups and started when the patient was disconnected from the mechanical ventilator and ended when the delivery of oxygen therapy was complete.

Hemodynamic variables, including systolic blood pressure (SBP), diastolic blood pressure (DBP), MBP, and heart rate (HR), were determined using bedside monitors. Respiratory frequency was measured by the observation of thoracic movements. These variables, in addition to SpO₂, were collected before extubation, immediately after extubation, every minute in the first 10 min immediately after the procedure, and at every 30 and 60 min after the procedure. The length mechanical ventilation, orotracheal intubation, ICU stay, and hospital stay were also calculated.

All subjects were followed up during the hospital stay to evaluate the incidence of postoperative complications, which were classified as infectious, hemodynamic, neurological, or others. Infectious pulmonary complications were classified as tracheobronchitis and pneumonia, according to the guidelines of the Committee for Hospital Infection Control⁹. Tracheobronchitis: presence of fever (temperature $\geq 37.5^{\circ}\text{C}$), increased amount of lung secretion with a purulent appearance, and absence of new infiltrate in pulmonary parenchyma, as assessed by thoracic radiography. Pneumonia: crackles on auscultation or dullness to percussion, and one of the following criteria 1) positive blood culture, sputum with pus or other changes, bacterial isolation from biopsy or bronchoalveolar lavage samples; 2) alterations in the thoracic radiological examination, with the presence of a new or progressive infiltrate, consolidation, cavitation, or pleural effusion.

The analysis of costs was based on the materials used in the suctioning procedure and the time spent by the professionals involved. In the ES group, the materials used were 20-mL syringes, suctioning catheter, airway secretion collector, sterile gloves, procedure gloves, and surgical masks. The materials used in the NES group were procedure gloves, surgical mask, and syringe. Endotracheal suctioning was performed by two professionals.

Statistical analysis

The primary outcome was the rate of occurrence of postoperative pulmonary complications in the study groups (5%). Anthropometric characteristics, cardiopulmonary bypass time, mechanical ventilation time, ICU stay, and hospital stay were compared using Student t-test or its equivalent Mann-Whitney test. Two-way repeated measures analysis of variance (RM-ANOVA) and Tukey test were used for multiple comparisons. The chi-square test (χ^2) was used to determine the prevalence of pulmonary complications. SPSS (version 21) was used for statistical analysis. A significance level of $p < 0.05$ was chosen for all tests.

Results

A total of 504 individuals were recruited to the study, as shown in Figure 1. From these, 276 (55%) were excluded: a) presence of bronchial secretion (20%); b) cardiopulmonary bypass time > 120 min (20%); c) PaO₂/FiO₂ < 200 (38%); d) other causes, including mechanical ventilation time > 12 hours (4%), hemodynamic instability requiring a new surgical approach (4%), use of mechanical circulatory assistance (6.5%), accidental extubation (1.8%), convulsion (0.36%), and bronchoaspiration (0.36%). A total of 228 subjects were randomly assigned to one of the two study groups (114 subjects to each group).

The characteristics of the participants and hospital stay are presented in Table 1. There was a predominance of male patients (69% ES and 59% NES). Anthropometric data and hospital stay were not significantly different between the groups, except for cardiopulmonary bypass time, which was lower in the ES group ($p = 0.02$).

Figure 1. Flow chart of patient's study

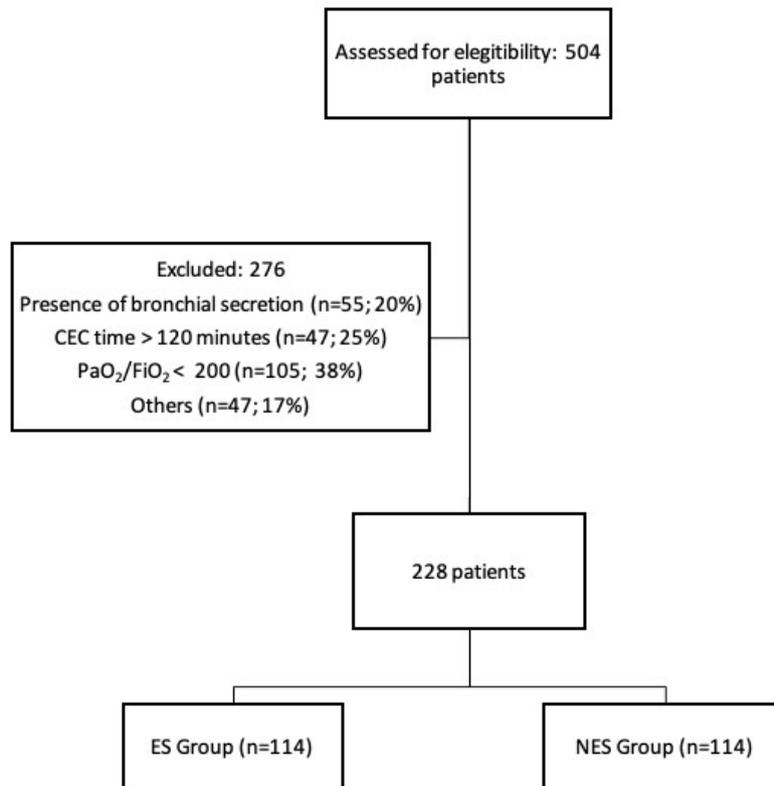


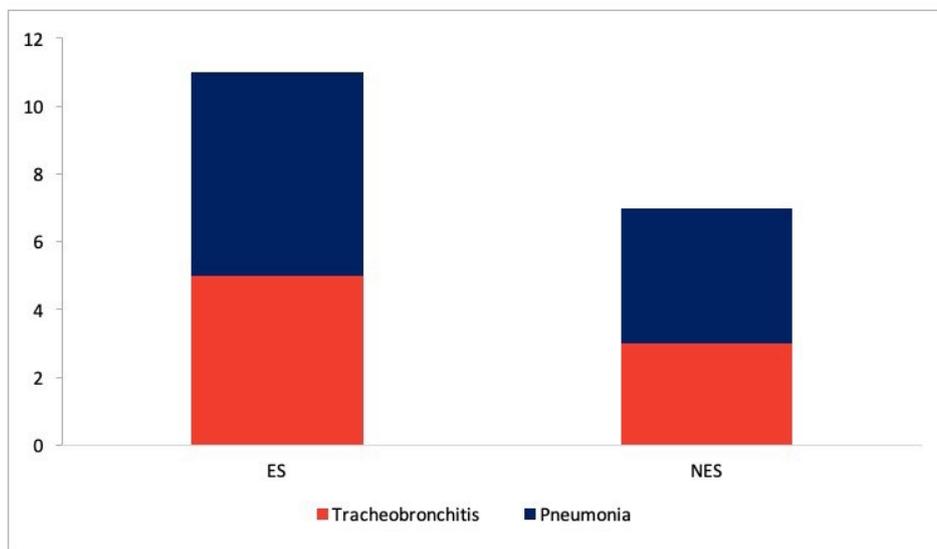
Table 1. Characteristics anthropometrics, surgical and stay of the ES (Endotracheal Suctioning) and NES (ncn endotracheal suctioning) groups

| | ES (n = 114) | NES (n = 114) | <i>p</i> |
|---|------------------|------------------|------------|
| Age (years) | 62 (55–69) | 60 (53–65) | .12 |
| Weight (kg) | 69.35±11.65 | 67.69±11.70 | .30 |
| Height (m) | 1.66 (1.60–1.72) | 1.65 (1.58–1.71) | .16 |
| Body Mass Index (kg/m ²) | 25 (22–27) | 25 (22–27) | .93 |
| Surgery time, (minutes) | 315± 77 | 330± 73 | .12 |
| CEC time, (minutes) | 65 (52–87) | 78 (56–97) | .02 |
| Duration of Mechanical Ventilation, (minutes) | 315 (210–390) | 286 (220–370) | .22 |
| ICU lenght of stay (days) | 3 (2-4) | 3 (2-4) | .56 |
| Hospital lenght of stay (days) | 8 (7-12) | 9 (7-13) | .96 |

Postoperative complications

Postoperative pulmonary complications were present in 7.8% of the study sample. In the ES group, five individuals with tracheobronchitis (8%) and six with pneumonia (10%). In the NES group, these complications occurred in three (5%) individuals and four (7%) individuals, respectively (Figure 2).

Figure 2. VCase number of infection pulmonary complications in ES and NES groups. Chi-square test (χ^2)



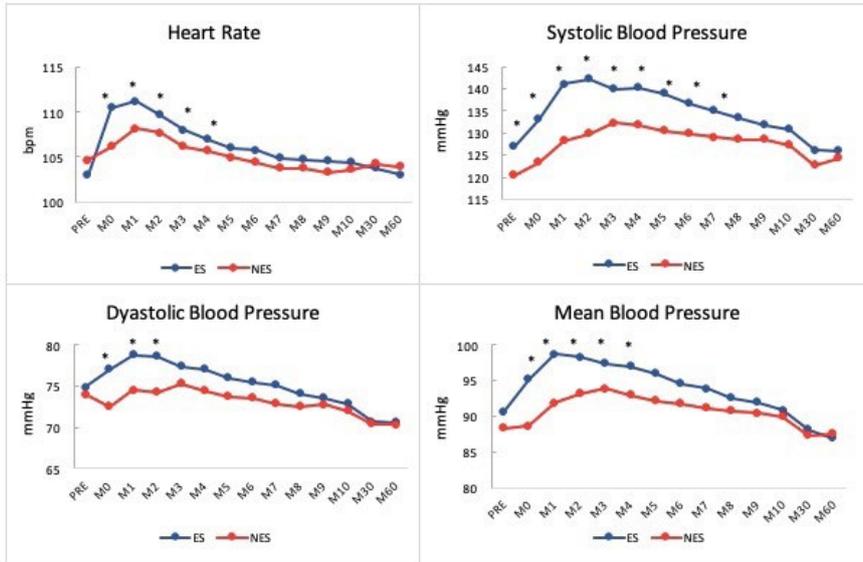
Effects on heart rate and arterial blood pressure

Figure 3 illustrates the variations in the HR, SBP, DBP, and MBP.

Immediately after extubation (minute 0, M0), HR values showed a significant increase up to M5, with no difference between the groups ($p=0.55$). The highest values were recorded at M1 and ranged from 102 (pre-extubation) to 111 beats/min in ES and from 105 to 108 beats/min in NES.

The intergroup difference in SBP was statistically significant ($p=0.009$). The highest values were observed in ES before extubation, immediately after extubation, and until M7. The highest values occurred from M0 to M2 in ES and at M3 in NES. The intergroup differences in the average DBP values were statistically significant from M0 to M2. DBP increased in ES but decreased in NES. The intergroup difference in MBP was statistically significant from M0 to M4. In both groups, MBP returned to its initial levels at M8 (Figure 3).

Figure 3. Hemodynamic values before and after extubation procedure in ES and NES groups



PRE: before extubation, M0= extubation's moment, M1= 1st minute after extubation, M2= 2nd minute after extubation, M3= 3rd minute after extubation, M4= 4th minute after extubation, M5= 5th minute after extubation, M6= 6th minute after extubation, M7= 7th minute after extubation, M8= 8th minute after extubation, M9= 9th minute after extubation, M10= 10th minute after extubation, M30= 30th minute after extubation, M60= one hour after extubation, * p < 0,05

Anova Two Way RM/ Anova One Way RM/ Tukey Test

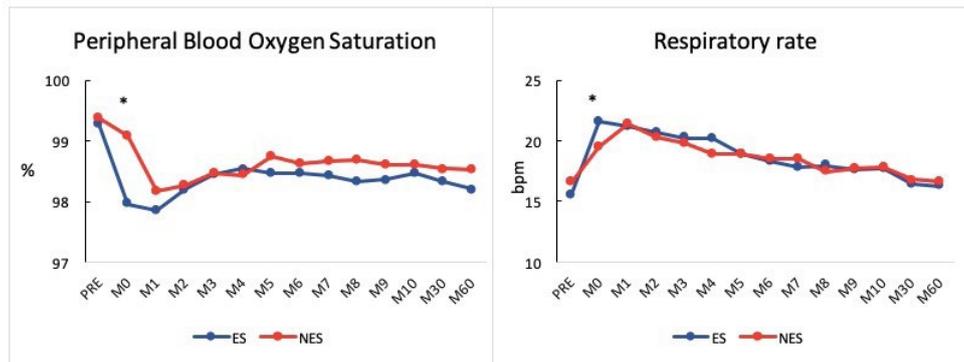
Effects on oxygenation and respiratory frequency

Figure 4 illustres the variations in respiratory frequency and SpO2.

Endotracheal suctioning significantly increased SpO2 and the respiratory frequency, and the intergroup differences were significant at M0. In the ES group, SpO2 decreased from 99.3% to 98.0% (pre-extubation vs. M0); the values at other time points were significantly lower than those at pre-extubation. In the NES group, the lowest SpO2 was at M1, and the value returned to baseline after 60 min.

The respiratory frequency in ES and NES increased at M0, with a significant intergroup difference (p=0.002). In the ES group, the increase occurred from 15.5 to 21.6 inspirations/min (pre-extubation vs. M0) and remained elevated up to M4; subsequently, the reductions were gradual up to M60, when they returned to baseline. In NES, a significant elevation occurred up to M5 and returned to baseline at M10 (Figure 4).

Figure 4. Respiratory values before and after extubation procedure in ES and NES groups



PRE= before extubation, M0= extubation's moment, M1= 1st minute after extubation, M2= 2nd minute after extubation, M3= 3rd minute after extubation, M4= 4th minute after extubation, M5= 5th minute after extubation, M6= 6th minute after extubation, M7= 7th minute after extubation, M8= 8th minute after extubation, M9= 9th minute after extubation, M10= 10th minute after extubation, M30= 30th minute after extubation, M60= one hour after extubation, * p< 0,05

Anova Two Way RM/ Anova One Way RM/ Tukey Test

Procedure costs and time

At the time of the study, the calculated material cost of the aspiration procedure was R\$7.23 for each patient from the ES group with total cost of R\$824.22. Which are: 1 pair of sterile gloves R\$1.45, 2 pairs of procedure gloves R\$0.40, 2 surgical masks R\$0.12, 1 20ml syringe R\$0.27, 1 probe suction pump with valve number 12 R\$0.39 and 500ml secretion collector R\$4.60. In the NES group, the individual cost was R\$0.79, which are: 2 pairs of procedure gloves R\$0.40, 2 surgical masks R\$0.12, 1 20ml syringe R\$0.27. The total cost of was R\$90.06¹⁰.

In the ES group, the length of the procedure for each patient was 2 minutes and 68 seconds. The time spent by the professionals was 357 minutes and 20 seconds, totaling 714 minutes and 40 seconds, or 12 hours 30 minutes and 6 seconds, considering that two professionals were involved in the aspiration procedure. In the NES group, the length of the procedure for each patient was 28 seconds, and the time spent by one professional was 53 minutes and 20 seconds.

Discussion

In this study, participants without signs of bronchial secretion were extubated without endotracheal suctioning procedure. This strategy did not affect the incidence of pulmonary complications and the length of hospital stay. Conversely, endotracheal suctioning caused greater cardiovascular stress, demanded more time from the professionals, and increased costs.

Pulmonary dysfunctions are frequent in the immediate postoperative period of cardiac surgery. The most common complications are atelectasis and pleural effusions and are mainly due to sternotomy, use of anesthetic drugs, length of mechanical ventilation, and opening of the pleural cavity.

The incidence of pulmonary complications, defined as those that produce identifiable disease or significant dysfunction that affects clinical evolution, tends to be lower in the postoperative period of cardiac surgery. In this institution, these complications are classified as tracheobronchitis and pneumonia, according to criteria established by Committee for Hospital Infection Control⁹.

In this study the incidence of postoperative pulmonary infections ranged from 7.8% (3.5% of tracheobronchitis and 4.3% of pneumonia). Institutional data show the incidence of postoperative pulmonary infection is between 5.3 to 9.9¹¹. In others studies that involved subjects in the postoperative period of myocardial revascularization, undergoing physical therapy, this incidence ranged between 7.1%¹² and 10%¹³. For valve surgery, 11% of subjects who were considered to be at low surgical risk developed pulmonary infection¹⁴.

The infection rate did not change regardless of the use of endotracheal suctioning before extubation. Physical therapy is routinely provided to all surgical subjects to improve pulmonary volumes and maintain airway free of bronchial secretion and may decrease the incidence of pulmonary infections. It is known that most patients undergoing to cardiac surgery present restrictive ventilatory pattern, with the loss of pulmonary volumes and ventilatory capacity. In addition pulmonary infections are associated with other factors, including smoking, alcoholism, and the degree of cardiac failure before surgery¹⁵.

The absence of detectable bronchial secretion justified the procedure of extubating individuals without perform endotracheal suctioning. The clinical evolution of these individuals confirmed that endotracheal suctioning was not indicated for these cases and therefore should be avoided.

The length of hospital stay in the postoperative period was similar between the groups, ranging from 9 to 17 days, and this result is in line with institutional data¹¹. The preoperative criteria used in our subjects allowed their classification as having a low surgical risk with a probable complication-free clinical evolution. Although 24.5% of them developed postoperative complications, this magnitude was not significant to change the clinical evolution and the length of hospital stay.

Acute effects of endotracheal suctioning

It is known that the extubation procedure changes the cardiorespiratory system. We observed that regardless of the study group, extubation increased the HR and arterial blood pressure, particularly in the first 5 min. However, the largest increase occurred during endotracheal suctioning. This result is, in part, due to the insertion of the aspiration catheter into the

tracheal region, which has several mechanoreceptors¹⁶. The consequent irritation of the airways can trigger hemodynamic oscillations via autonomic modulation and increase in the HR^{19,20}. Other effects such as vagal stimulation, bronchospasm, reduction of the oxygen supply to the lungs, and microatelectasis have also been described¹⁷. These effects were not found in our study; the possibility of such occurrences made the procedure selective and recommended only in specific cases.

We did not observe the occurrence of adverse effects, including cardiac arrhythmias¹⁸. Oxygen supplementation (FIO₂ = 1) during suctioning probably avoided hypoxemia and arrhythmias. The variations in the oxygenation observed in our subjects were small, and none of the them evaluated presented hypoxemia. Conversely, although hyperoxygenation prevents hypoxemia, it does not prevent the effect of negative pressure and of the disconnection of the mechanical ventilation on the pulmonary volume that may cause microatelectasis.

Arterial blood pressure should be monitored in the postoperative period of cardiac surgery because it is one of the vital signs that indicate early changes in cardiovascular function¹⁸. SBP increases during and after endotracheal suctioning. The act of coughing, which is common during endotracheal suctioning and extubation procedures, can cause tachycardia, hypertension, and excessive release of catecholamines, consequently increasing the demand of the myocardium for oxygen^{19,20}.

Our results indicate that during extubation, DBP increased in the ES group and decreased in the NES group; however, immediately after extubation, this variable increased in both groups. The positive pressure used in mechanical ventilation increases pleural pressure and, consequently, the pressure in the pericardial region. The pressure generated within the pericardial sac may cause diastolic restriction of the left ventricle, decrease the overall transmural pressure of the cardiac chambers, and affect diastolic ventricular function. Positive pressure withdrawal causes the return of pleural pressure to sub-atmospheric values, decompression of the vena cava, and increased venous return, resulting in increased filling of the heart chambers and increased cardiac output²¹. The decrease in the intrathoracic pressure and increase in cardiac output leads to the immediate

increase in arterial pressure, as demonstrated in our results. However, over time, the pressure tends to normalize by the increased sense of comfort reported by the patient, greater control of pain, and the effect of analgesic drugs²².

We observed that the respiratory frequency increased significantly in the ES group. It is possible that the negative pressure generated by aspiration causes different degrees of pulmonary collapse and increases the respiratory frequency to maintain constant ventilation. However, the respiratory frequency increased in both groups, and this can be caused in part by the loss of pulmonary volume after pressure support withdrawal, postoperative pain, mechanical restriction, and presence of drains, among others^{23,24}.

The careful evaluation of the real need for tracheal suctioning in subjects in the immediate postoperative period of cardiac surgery avoids common practice, reduces health costs, and optimizes the period of physical therapy.

Endotracheal suctioning is a risk factor to the patient. Doing good (beneficence) and without risks (not maleficence) are ethical aspects involved in health care. The procedure with a lower risk-benefit should be chosen in care practice to avoid unnecessary risks and wrong choices.

Therefore, routine endotracheal suctioning should be questioned and carefully evaluated, and its indication needs to be selective and based on actual requirements. Otherwise, this procedure becomes invasive and increases both health costs and the risk to the patients.

The limitations of study were: a) the absence of availability of a cardiac output monitor to analyze hemodynamic variables (HR, SBP, DBP, MBP) and cardiac output. The equipment was intended for the most serious, who did not meet the inclusion criteria of the study; b) the absence of blood gas analysis before the patient leaves the operating room. Baseline blood gases for evaluation of inclusion in the study collected on admission of the patient to the ICU. The influence of transport on manual ventilation in

the PaO₂/ FiO₂ ratio was not evaluated; c) pulmonary complications based on medical records in electronic medical records.

Conclusions

In our study, the suppression of endotracheal suctioning before extubation in the immediate postoperative period of cardiac surgery in patients without signs of bronchial secretion did not affect the incidence of pulmonary complications and hospital stay. On the other hand, this suppression optimized the professional time and reduced costs.

Moreover, extubation caused hemodynamic and respiratory alterations without clinical repercussions. Endotracheal suctioning potentiated these changes and increased costs.

Author contributions

Campos A participated in the conception, design, collection of research data and writing of the article. Rabelo ABL participated in the search and data collection, literature review and article writing. Barros JO participated in the search and statistical analysis of the data, interpretation of results, literature review, data collection and writing. Nozawa E participated in the study design and critical review of the manuscript. Hajjar LA and Galas FRG participated in the critical review of the manuscript. Feltrim MIZ participated in the conception, design, statistical analysis and interpretation of data and writing of the article.

Competing interests

No financial, legal or political competing interests with third parties (government, commercial, private foundation, etc.) were disclosed for any aspect of the submitted work (including but not limited to grants, data monitoring board, study design, manuscript preparation, statistical analysis, etc.).

References

1. Day T, Farnell S, Haynes S, Wainwright S, Wilson-Barnett J. Tracheal suctioning: an exploration of nurses' knowledge and competence in acute and high dependency ward areas. *J Adv Nurs*. 2002;39(1):35-45. doi: [10.1046/j.1365-2648.2002.02240.x](https://doi.org/10.1046/j.1365-2648.2002.02240.x)

2. Day T, Farnell S, Wilson-Barnett J. Suctioning: a review of current research recommendations. *Intensive Crit Care Nurs.* 2002;18(2):79-89. doi: [10.1016/s0964-3397\(02\)00004-6](https://doi.org/10.1016/s0964-3397(02)00004-6)
3. Jelic S, Cunningham JA, Factor P. Clinical review: Airway hygiene in the intensive care unit. *Crit Care.* 2008;12(2):209. doi: [10.1186/cc6830](https://doi.org/10.1186/cc6830)
4. Lucchini A, Zanella A, Bellani G, Gariboldi R, Foti G, Pesenti A et al. Tracheal Secretion Management in the Mechanically Ventilated Patient: Comparison of Standard Assessment and an Acoustic Secretion Detector. *Respir Care.* 2011;56(5):596-603. doi: [10.4187/respcare.00909](https://doi.org/10.4187/respcare.00909)
5. Restrepo RD, Brown JM, Hugles JM. American Association for Respiratory Care. AARC Clinical Practice Guidelines. Endotracheal suctioning of mechanically ventilated patients with artificial airways. *Respir Care* 2010;55(6):758-64.
6. Favretto DO, Silveira RCCP, Canini SRMS, Garbin LM, Martins FTM, Dalri MCB. Endotracheal suction in intubated critically ill adult patients undergoing mechanical ventilation: a systematic review. *Rev Latino-Am Enfermagem.* 2012;20(5):997-1007. doi: [10.1590/S0104-11692012000500023](https://doi.org/10.1590/S0104-11692012000500023)
7. Celik SS, Elbas NO. The standard of suction for patients undergoing endotracheal intubation. *Intensive Crit Care Nurs.* 2000;16(3):191-8. doi: [10.1054/iccn.2000.1487](https://doi.org/10.1054/iccn.2000.1487)
8. Vanner R, Bick E. Tracheal pressures during open suctioning. *Anaesthesia.* 2008;63(3):313-5. doi: [10.1111/j.1365-2044.2007.05348.x](https://doi.org/10.1111/j.1365-2044.2007.05348.x)
9. Subcommittee of hospital infection control of Heart Institute Medical School of the University of Sao Paulo [Internet]. 2014 [cited 7 November 2014]. Available from: www.incor.usp.br/sites/incor2013/index.php/component/content/article/197-intranet/manuais-normas-e-rotinas/comissoes/697-intranet-manuais-normas-e-rotinas-comissoes-subcomissao-de-controle-de-infeccao
10. Department of Material Division of Heart Institute Medical School of the University of Sao Paulo. [Internet]. 2014. [accessed in 2014 June 04]. Available from: http://www.hc.fm.usp.br/images/pdf/nilo/compras/relacaocompras_hcfmusp_2014/Relacao_de_compras_JAN-2014.pdf
11. Institut de Cardiologie de Montréal. Annual Activities Report of Heart Institute 2014 [Internet]. 2014 [accessed in 2014 dec 21]. Available from: https://www.icm-mhi.org/sites/default/files/docs/ficm/corrige_icm_annual_report_2014-15.pdf
12. Stiller K, Jenkins S, Hall B. Efficacy of Breathing and Coughing Exercises in the Prevention of Pulmonary Complications After Coronary Artery Surgery: To the Editor. *Chest.* 1995;107(2):587-588. doi: [10.1378/chest.107.2.587-a](https://doi.org/10.1378/chest.107.2.587-a)
13. Jenkins SC, Soutar SA, Loukota JM, Johnson LC, Moxham J. Physiotherapy after coronary artery surgery: are breathing exercises necessary? *Thorax.* 1989;44(8):634-639. doi: [10.1136/thx.44.8.634](https://doi.org/10.1136/thx.44.8.634)
14. Franco SS, Malbouisson LMS, Grinberg M, Feltrim MIZ. A propose of pulmonary dysfunction stratification after valve surgery by physiotherapeutic assistance level. *Revista Brasileira de Cirurgia Cardiovascular.* 2015;30(2):188-97. doi: [10.5935/1678-9741.20150006](https://doi.org/10.5935/1678-9741.20150006)
15. Lawrence VA, Cornell JE, Smetana GW. Strategies To Reduce Postoperative Pulmonary Complications after Noncardiothoracic Surgery: Systematic Review for the American College of Physicians. *Ann Intern Med.* 2006;144(8):596-608. doi: [10.7326/0003-4819-144-8-200604180-00011](https://doi.org/10.7326/0003-4819-144-8-200604180-00011)
16. Brucia J, Rudy E. The effect of suction catheter insertion and tracheal stimulation in adults with severe brain injury. *Heart & Lung.* 1996;25(4):295-303.
17. Kerem E, Yatsiv I, Goitein KJ. Effect of endotracheal suctioning on arterial blood gases in children. *Intensive Care Med.* 1990;16(2):95-99.
18. Dias FS, Rezende E, Mendes CL, Réa-Neto A, David CM, Schettino G et al. Part II: basic hemodynamic monitoring and the use of pulmonary artery catheter. *Rev Bras Ter Intensiva.* 2006;18(1):63-77. doi: [10.1590/S0103-507X2006000100012](https://doi.org/10.1590/S0103-507X2006000100012)
19. Paulsian R, Salem MR, Joseph NJ, Braverman B, Cohen HC, Crystal GJ et al. Hemodynamic Responses to Endotracheal Extubation After Coronary Artery Bypass Grafting. *Anesth Analg.* 1991;73(1):10-5. doi: [10.1213/00000539-199107000-00003](https://doi.org/10.1213/00000539-199107000-00003)
20. Carlos RV, Bittar CS, Lopes MR, Auler Júnior JOC. Variation of systolic blood pressure as a method of diagnosis of hypovolemia during anesthesia for cardiac surgery. *Rev Bras Anesthesiol.* 2005;55(1):3-18. doi: [10.1590/S0034-70942005000100002](https://doi.org/10.1590/S0034-70942005000100002)
21. André AC, DelRossi A. Hemodynamic management of patients in the first 24 hours after cardiac surgery. *Crit Care Med.* 2005;33(9):2082-93. doi: [10.1097/01.ccm.0000178355.96817.81](https://doi.org/10.1097/01.ccm.0000178355.96817.81)
22. Giacomazzi CM, Lagni VB, Monteiro MB. Postoperative pain as contributor to pulmonary function impairment in patients submitted to heart surgery. *Braz J Cardiovasc Surg.* 2006;21(4):386-92. doi: [10.1590/S0102-76382006000400008](https://doi.org/10.1590/S0102-76382006000400008)
23. Guizilini S, Gomes WJ, Faresin SM, Bolzan DW, Buffolo E, Carvalho AC et al. Influence of Pleurotomy on Pulmonary Function After Off-Pump Coronary Artery Bypass Grafting. *The Annals of Thoracic Surgery.* 2007;84(3):817-822. doi: [10.1016/j.athoracsur.2007.04.062](https://doi.org/10.1016/j.athoracsur.2007.04.062)
24. Maggiore SM, Lellouche F, Pignataro C, Girou E, Maitre B, Richard JCM et al. Decreasing the Adverse Effects of Endotracheal Suctioning During Mechanical Ventilation by Changing Practice. *Respir Care.* 2013;58(10):1588-97. doi: [10.4187/respcare.0226](https://doi.org/10.4187/respcare.0226)