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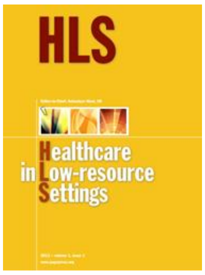

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Original Research/Review

The effectiveness of hyperoxygenation in preventing oxygen desaturation in intubated infants treated with endotracheal suctioning

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Significance for public health: Endotracheal suctioning is an essential nursing intervention for intubated infants treated with invasive mechanical ventilation. However, this procedure causes various side effects, including hypoxemia, and often requires hyperoxygenation. Despite the effectiveness of hyperoxygenation, there are limited reports on its use among infants. The study indicates a notable oxygen saturation variation among infants who underwent endotracheal suctioning with hyperoxygenation.

Abstract

Endotracheal suctioning is an effective nursing intervention for intubated infants undergoing invasive mechanical ventilation. However, this intervention has the potential to cause side effects, such as hypoxemia, which typically requires hyperoxygenation. Despite the widespread use of hyperoxygenation in clinical practice, there are limited reports on its effectiveness in infants. This study aims to determine the effect of hyperoxygenation on oxygen saturation of intubated infants.

The study procedures were carried out using a quasi-experimental method with a cross-over approach. In addition, the sample population comprised 22 intubated infants who were treated at the perinatology unit of Dr. Cipto Mangunkusumo Hospital in Jakarta from March to April 2018. The participants were then divided into 2 groups based on their condition, and oxygen saturation level was assessed. The intervention comprised endotracheal suctioning with and without hyperoxygenation, with a 3-hour washing period. Data collection was performed at different measurement intervals, namely before, during, and after suctioning, followed by statistical analysis.

The paired-sample t-tests and Wilcoxon test showed that there was a significant difference in oxygen saturation at certain measurement intervals ($p=0.006$; $p=0.010$; $p=0.001$; $p=0.001$; $p=0.001$). In addition, Friedman test also showed the presence of a significant difference in the reduction of oxygen saturation between the control and intervention groups ($p=0.001$).

In conclusion, hyperoxygenation had the potential to prevent the reduction of oxygen saturation during endotracheal suctioning in intubated infants. However, individual assessment of the need for suctioning and hyperoxygenation was necessary for a safe and effective procedure.

Introduction

Respiratory insufficiency in infants is a prevalent challenge among newborns, which typically necessitates intensive care at the Neonatal Intensive Care Unit (NICU).[1–3] Several studies have shown that the majority of infants treated at the NICU often require invasive mechanical ventilation (MV) and the use of endotracheal tube (ETT) to create a connection with the ventilator.[4] However, ETT causes mild inflammation in the airway mucosa and suppresses mucociliary mechanisms, leading to an impairment in the ability to mobilize and expectorate secretions. The use of ETT also impairs cough reflexes, causing increased mucus production and accumulation in the airways.[5,6] This accumulation has the potential to disrupt the ventilation of infants, thereby requiring frequent endotracheal suctioning to maintain the patency of the airway.[7–9]

According to previous studies, endotracheal suctioning is a routine nursing intervention for intubated patients to drain mucus secretion. In addition, it is often performed in patients who cannot remove secretions to maintain airway patency and provide optimal ventilation.[8] Several reports have shown that the use of proper endotracheal suctioning technique provides various benefits, namely improving respiratory sounds and gas exchange, decreasing airway resistance and PIP (peak inspiratory pressure) of the ventilator, improving dynamic lung compliance, as well as enhancing oxygen saturation ($SpO2$) and arterial blood gas.[4]

In infants, endotracheal suctioning is often performed using ETT with a smaller diameter, leading to challenges during the procedure and increasing the risk of complications. ETT with an internal diameter of $\leq$ 4mm has been reported to have the potential to cause an immediate reduction in dynamic lung compliance and expired tidal volume (TV). This shows that ineffective endotracheal suctioning can cause ETT obstruction, atelectasis, as well as ineffective ventilation and oxygenation, thereby necessitating re-intubation.[4] Although suctioning is essential for improving ventilation and oxygenation, the procedure is associated with various complications and risks. These include bleeding of mucosal airways, infection, atelectasis, hypoxia, hypoxemia, cardiovascular instability, and elevated intracranial pressure,[5,10] with hypoxia and hypoxemia being the most common and severe. [5,9,11] In addition, stress due to the procedure can influence the metabolic rate and increase oxygen demand,[12] showing the need for hyperoxygenation. According to previous studies, hyperoxygenation is the administration of oxygen fraction (FiO2) at a percentage greater than the baseline requirement before suctioning up to 100%.[4,9] Although this technique is widely used in clinical practice to avoid hypoxemia, there are limited reports on its effectiveness in intubated infants. Therefore, this study aims to determine the effectiveness of hyperoxygenation in endotracheal suctioning compared to suctioning without hyperoxygenation.

Materials and Methods

Study Design

This was a quasi-experimental study with a cross-over approach, which was carried out to determine the immediate effects of hyperoxygenation in endotracheal suctioning compared to endotracheal suctioning without hyperoxygenation on oxygen saturation in 2 different groups of newborn infants. Each sample received 2 types of intervention, namely endotracheal suctioning with hyperoxygenation (for the intervention group) and endotracheal suctioning without hyperoxygenation (for the control group). In addition, this was a single-centered study, and trials were conducted based on standard protocols as well as good clinical practice and national ethical guidelines.

Sample and setting

The sample population comprised 22 infants who were treated in Dr. Cipto Mangunkusumo Hospital, the National Referral Hospital located in Central Jakarta, Indonesia from March to April 2018. In addition, the participants were allocated based on their condition before suctioning procedure. Infants were eligible for admission when mechanically ventilated through ETT and had an indication for endotracheal suctioning. The indications included clinical history of decreased SpO2 in previous suction, visible secretions in the ETT, audible secretions, changes in respiratory rate, and decreased SpO2 immediately before suctioning. Exclusion criteria included ventilation using high-frequency oscillating (HFO) ventilation, the presence of conditions, requiring perfusion, such as hypotension, anemia, cold stress, congenital heart disease, and presence of skin lesions detected by oxygen saturation device based on blood saturation number, and chronological age of more than 28 days. The sample size estimation was performed based on a previous study by Walsh et. al (1987), which used 16 participants.[13] This study compared supplemental oxygenation or hyperoxygenation during tracheobronchial hygiene on the transcutaneous partial pressure of oxygen (TcPO2). The results showed that the standard deviation of change in TcPO2 was 17.58 torr and the mean difference between groups considered significant (effect size) was 22.54 torr. [13] Based on these results, the calculated minimum sample size per group was 19, and this present report used a total of 22 infants. To minimize the between-subject variability, the participants used 2 types of ventilators with the same specifications. Suction procedure was carried out in the same position (supine) and was supported by nesting by the same nurse using the same standard intervention process.

Intervention

The participants were allocated into 2 sequential enrollment schemes based on infants' condition before interventions (conditions that require suctioning), hence, the section was not carried out routinely.[14] The participants received 2 different interventions, namely endotracheal suctioning with and without hyperoxygenation. This showed when the participants had a significant decrease in SpO2 ≥ 2 points (%) before suctioning procedure compared to the previous condition, hyperoxygenation was performed and the next suctioning was carried out without hyperoxygenation with infants being placed in group A (GA). In group B (GB), when there was a significant increase in SpO2 ≥ 2 points (%), the reverse process was carried out. Endotracheal suctioning intervention was performed based on the hospital's protocol by 2 individuals (the researcher and research assistant) as recommended by professional organizations to ensure the safety of the participants.[15,16]

Intervention in group A comprised endotracheal suctioning procedure when infants showed indications. These indications included clinical history of decreased SpO2 in previous suctioning, decreased SpO2 before suctioning, visible secretions in the ETT, audible secretions, coarse and/or decreased breath sounds, and changes in respiratory rate and pattern. Before the first endotracheal suctioning was carried out, hyperoxygenation was performed by pressing the "suctioning support" button on the ventilator, leading to an additional 20% FiO2 for 2 minutes. In this study, hyperoxygenation was performed 30 seconds before suctioning. Several reports showed that endotracheal suctioning must not exceed 10 seconds, with each suctioning comprising 3 probe insertions. Subsequently, the second suctioning was performed after infants' saturation returned to normal range after decreasing due to the first suctioning and the third suctioning. The procedures were performed in a supine position and the participants were supported by nesting. The use of nesting in premature infants facilitated relaxation and comfort to minimize pain.[17] Group B underwent the same intervention as group A, but without hyperoxygenation before endotracheal suctioning.

Data collection and analysis

In this study, pre and post-suctioning oxygen saturation (SpO2) was obtained in 6 different measurements, namely 60 seconds before suctioning (T-1), immediately after hyperoxygenation (T0), after the first suctioning repetition (T1), after the second suctioning repetition (T2), after the third repetition (T3), and 3 minutes after suctioning (T4). Moreover, the socio-demographic characteristics, gestational age, and birth weight of the participants were also measured. Statistical analysis was performed using SPSS version 16, and the data normality was assessed using Shapiro Wilks test. The demographic data were evaluated by measuring distribution, frequency, and the central tendency for birth weight and gestational age. The differences across groups on infants' oxygen saturation (SpO2) were analyzed using paired-sample t-tests (normal data), and Wilcoxon (abnormal data). For data within groups, analysis was carried out using Friedman test, followed by Post-Hoc Wilcoxon test. Data were reported as mean difference (95% CI) and p-values < 0.05 were considered significantly different.

Ethical Considerations

This study was conducted after obtaining approval from the Ethics Committee of the Faculty of Nursing, University of Indonesia (No.139/UN2.F12.D/HKP.02.04/2018), hospital's approval where the procedures were conducted, and written consent from parents or guardians.

Results and Discussion

Participants' Characteristics

The characteristics of the participants consisted of gestational age and birth weight, which were described in Table 1. The results showed that the mean gestational age was 33.23 weeks and the majority of infants (36.4%) were late preterm (gestational age 34-36 weeks), with low birth weight (50%).

The majority of the participants were preterm infants, particularly late preterm, with gestational age ranging from 27 to 36 weeks and low birth weight of 1000 to 2499 grams. Preterm infants with low birth weight had a great risk for respiratory complications due to the late maturity of the respiratory system.[18]

Some of the problems affecting the respiratory system of preterm infants and causing breathing difficulty were surfactant deficiency that led to respiratory distress syndrome (RDS), immaturity of respiratory control central causing apnea, and increased risk of airway obstruction due to smaller respiratory airways.

The most common respiratory complication in preterm infants with low birth weight was RDS caused by lung immaturity and lack of surfactant, which affected the poorly compliant lungs with poor gas exchange. This respiratory complication could cause respiratory failure that required invasive or non-invasive MV.

The Differences in oxygen saturation (SpO2) across groups

The results of the paired t-test in Table 2 and Figure 2 showed that there were significant differences in oxygen saturation at several measurements between the intervention and control groups. These differences were observed before the intervention (hyperoxygenation), in the first, second, and third suctioning repetition, and 3 minutes after mucus suctioning. Based on the results, the mean oxygen saturation of the intervention group was greater compared to the controls at T0, T1, T2, T3, and T4.

Figure 2 showed that the intervention group experienced an increase in oxygen saturation after hyperoxygenation. After the first, second, and third suctioning repetitions, oxygen saturation decreased but did not become a desaturation period where the percentage was less than 85%. These results were inconsistent with the control group, which experienced a decrease in oxygen saturation to desaturation after the third suctioning.

Oxygen saturation during endotracheal suctioning in this study was measured at 6 different periods, namely 60 seconds before suctioning, immediately after hyperoxygenation, after the first second, and third repetition, and three minutes after suctioning. The result showed that during endotracheal suctioning at first, second, and third suctioning repetition, there was higher oxygen saturation in the intervention group compared to the controls. Based on the results of the paired t-test and Wilcoxon test, there was a significant difference in oxygen saturation after the first, second, and third suctioning repetitions between the intervention and control groups. This was because the intervention group was given hyperoxygenation by giving an additional 20% of FiO2 for 2 minutes which could prevent and minimize the occurrence of hypoxemia in infants during suctioning.[4,7,13] Hyperoxygenation by adding FiO2 of 10-20% was adequate in preventing hypoxemia when suctioning through ETT.[7]

The Differences of Oxygen Saturation (SpO2) within Groups

Differences in oxygen saturation within the intervention and control groups were assessed using the Friedman test and continued with the post hoc Wilcoxon test (Table 3). The results of the intervention group showed that there were significant differences in several pairs of oxygen saturation measurement points, namely (T-1) - T0, T0 - T1, T0 - T2, and T0 -T3 but T0 - T4 did not show significant variation. This was different in the control group where there were differences in oxygen saturation with all measurement points (T1, T2, T3, T4).

This study showed differences in SpO2 before intervention after hyperoxygenation, showing that the administration of hyperoxygenation through the addition of 20% could increase SpO2 in infants before suctioning. SpO2 after hyperoxygenation was significantly different from the value in the first, second, and third suctioning repetitions in both groups. However, the decrease in SpO2 in the control group was greater compared to the intervention group. This showed that endotracheal suctioning procedure was able to significantly reduce SpO2 despite hyperoxygenation. The decrease in SpO2 during suctioning procedure occurred due to the removal of air from the airways.[5] The administration of negative pressure during suctioning could also cause a collapse of distal airways and alveoli despite the use of appropriate pressure and technique, leading to a reduction of SpO2.[19] The use of the open suctioning method in this study comprised the temporary disconnection of MV from infants' ETT, thereby interrupting airflow from MV, and this could serve as another contributing factor.[20] Other studies comparing open and close suctioning in infants who underwent endotracheal suctioning showed that the participants were able to sustain SpO2 during the procedure with no significant difference. This was caused by the participants' ability to perform spontaneous pulmonary ventilation, leading to an increase in RR immediately after ETT suctioning as a compensation mechanism to sustain their SpO2.[21]

The result also showed that in the intervention group, there was no significant difference between SpO2 after hyperoxygenation (T1) compared to the value at 3 minutes after mucus suctioning (T4). Within 3 minutes after suctioning, the SpO2 level in the intervention group could return to the previous value. This proved that the administration of hyperoxygenation for 2 minutes could restore the value of SpO2 to the previous level and within the normal range (88%-93%). Different results were obtained in the control group where SpO2 at T1 significantly varied from T4. The results showed that within 3 minutes, SpO2 had not been able to return to the previous value and also had experienced desaturation (SpO2 less than 88%). These results were also consistent with previous studies where a group of preterm infants who received hyperoxygenation before suctioning experienced fewer episodes of hypoxemia compared to those who received suctioning without hyperoxygenation and needed less time to reach normal SpO2.[22] Exposure to non-physiological oxygen levels (hypoxia or hyperoxia) could cause ROP, and continuous or intermittent hypoxia typically reduced myelination and induced angiogenesis in preterm animals.[23]

The Comparison in Oxygen Saturation (SpO2) Reduction Across Groups

In this study, the reduction in oxygen saturation (SpO2) was calculated as the difference between oxygen saturation after hyperoxygenation and the lowest SpO2 recorded during endotracheal suctioning procedure. The result in Table 4 showed that there was a significant difference in SpO2 reduction in the intervention group compared to the control group where the decrease in oxygen saturation in the control group was greater.

The decrease in SpO2 in the control group was higher compared to the intervention group. This was because, in the intervention group, hyperoxygenation was performed before suctioning. Hyperoxygenation was performed on infants by adding 10-20% FiO2 above the previous oxygen percentage. A 20% increase in FiO2 before mucus suctioning was as effective as giving 100% oxygen.[4] Other studies also suggested hyperoxygenation in newborns by increasing FiO2 by 10% before mucus suctioning.[22] However, the administration of hyperoxygenation must be considered carefully to prevent complications. Some experts stated that the procedure must not be performed routinely, but only when the neonate had an indication, namely a clinical history of decreased SpO2 during previous suctioning and decreased SpO2 due to accumulation of secretions before suctioning.[4,22]

The correlation of Oxygen Saturation (SpO2) Reduction and Respondents' Characteristics

The correlation between decreased oxygen saturation (SpO2) and the participants' characteristics was analyzed to control the confounding factors, such as birth weight and gestational age. The result of the Pearson correlation in Table 5 showed that there was no relationship between the decrease in oxygen saturation (SpO2) with birth weight and gestational age. Based on these results, the difference in the decrease in oxygen saturation that occurred in the intervention and control groups was caused by hyperoxygenation intervention.

The present study showed that infants' oxygen saturation during and after endotracheal suctioning across both groups was significantly different. In addition, there was a significant difference in the reduction of oxygen saturation across both groups, with the control group possessing a higher value. The implementation was based on infants' response to care and previous suctioning. Several studies showed that nurses must conduct individual assessments of the need for suctioning and hyperoxygenation before performing endotracheal suctioning. When there there signs of infants requiring the procedure, namely visible secretions in the

ETT, audible secretions, coarse and/or decreased breath sounds, changes in respiratory rate[9] and pattern and accompanied by a decrease in oxygen saturation below 85% or 90% or a history of decreased saturation on previous suctioning, it was necessary to perform hyperoxygenation before endotracheal suctioning.[4] In addition, nurses had the option to rely on their clinical judgment or experience to decide the frequency of repetitions and the appropriate adjustment of FiO2, with a maximum allowance of 3 times suctioning repetitions and a FiO2 increase of up to 20%. Despite its potential, hyperoxygenation could also cause side effects, namely hyperoxemia, which was associated with serious long-term effects, such as retinopathy of prematurity (ROP), and chronic lung disease (CLD) due to oxygen free-radical damage[9]. Therefore, when nurses observed that suctioning with hyperoxygenation led to an increase in infants' oxygen saturation to 100%, this showed the possibility of reducing repetitions or decreasing FiO2 addition during subsequent suctioning to mitigate the risk of hyperoxemia. According to previous reports, there was also a crucial need to consider suctioning, specifically for extremely preterm infants during the first days of life. This was because a retrospective study showed an inverse relationship between the incidence of IVH and the number of suctioning.[6]

Conclusions

In conclusion, this study showed that an increase in FiO2 of 20% from the baseline value before endotracheal suctioning could be sufficient, effective, and safe to prevent hypoxemia and quickly return infants' oxygen saturation to normal ranges. The results obtained could be used as evidence and the basis for nurses in carrying out hyperoxygenation before endotracheal suctioning. The limitation of this study was the failure to set a standard percentage of the definition of a “decrease in oxygen saturation” and the use of a reduction from previous conditions. Therefore, future studies were advised to set a standard for decreasing oxygen saturation with a certain number, such as <85% or <93%.[24,25] Randomization of participants was not carried out randomly and completely, because it was based on the patients’ condition, hence, there was a risk of bias. Although this study used a crossover approach, it was classified as a quasi-experiment. Moreover, the procedures did not monitor respiratory indicators, such as ventilation per minute, TV, and long-term survival of infants. Future studies were expected to observe oxygenation in vital organs, such as the brain during mucus suctioning procedure using NIRS. The desaturation period that occurred in mucus suctioning must also be monitored and compared in the two groups.

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Table 1. Respondents' Characteristics Based on the Infants' Gestational Age and Birth Weight (n=22)

Variable		Mean	SD	Range (Min-Max)	95% CI
Gestational age (weeks)		33.23	3.380	27-38	31.73-34.73
Birth weight (grams)		1952.95	731.485	740-3520	1628.63-2277.28
Variable				**f**	**%**
Gestational age (weeks)	Extremely Premature			1	4.5
	Very Premature			6	27.3
	Moderately Premature			2	9.1
	Late Preterm			8	36.4
	Aterm			5	22.7
Birth weight (grams)	Extremely Low Birth Weight			2	9.1
	Very Low Birth Weigh			4	18.2
	Low Birth Weight			11	50
	Normal birth weight			5	23

Table 2 The differences in oxygen saturation (SpO_2) across groups (n=22)

Variable	Suction with hyperoxygenation (mean± sd)	95% CI	Suction without hyperoxygenation (mean± sd)	95% CI	*p value*
T-1	87.32±7.52	83.98-90.65	91.91±3.82	90.22-93.60	0.006*
T0	93.68± 5.43	91.28-96.09	91.91±3.82	85.80-89.84	0.147
T1	91.68 (77-100)	89.32-94.05	87.82 (76-95)	85.80-89.94	0.014**
T2	91.82±5.82	89.24-94.40	85.91±4.59	83.88-87.94	0.001*
T3	90±5.54	87.54-92.45	83.77±5.30	81.42-86.12	0.001*
T4	96 (87-99)	93.61-96.12	90 (85-96)	88.81-91.46	0.001**

* $p < 0.05$, there is a significant difference used *paired* t *test*
** $p < 0.05$, there is a significant difference used *Wilcoxon*

Table 3 The Differences of Oxygen Saturation (Spo_2) within Groups (n=22)

Variable	Suction with hyperoxygenation (mean± sd)	Suction without hyperoxygenation (mean± sd)
T-1	87.32±7.52	91.91±3.82
T0	95 (79-100)*	91.91±3.82
T1	91.86±5.41*	87.82±4.56*
T2	93.50 (76-99)*	85.91±4.59*
T3	91 (76-96)*	83.77±5.30*
T4	96 (87-99)	90.14±2.98*
p value	0.001	0.001

*Significant difference at T0 with some messurement points

Table 4 The Differences in Oxygen Saturation (Spo_2) Reduction Across Groups (n=22)

The decrease of SpO_2 in endotracheal suctioning	**Mean**	**SD**	**95% CI**	**p *value***
Intervention control (hyperoxygenation)	4.27	3.18	2.86-5.68	0.001
Control group (With hyperoxygenation)	8.5	4.21	6.68-10.41	

Paired t *test*

Table 5 The correlation of Oxygen Saturation (SpO_2) Reduction and Respondents' Characteristics

	Gestational age	**Birth weight**
SpO_2 reduction	r = 0.232	r = 0.050
	p = 0.130	p = 0.747

Pearson correlation

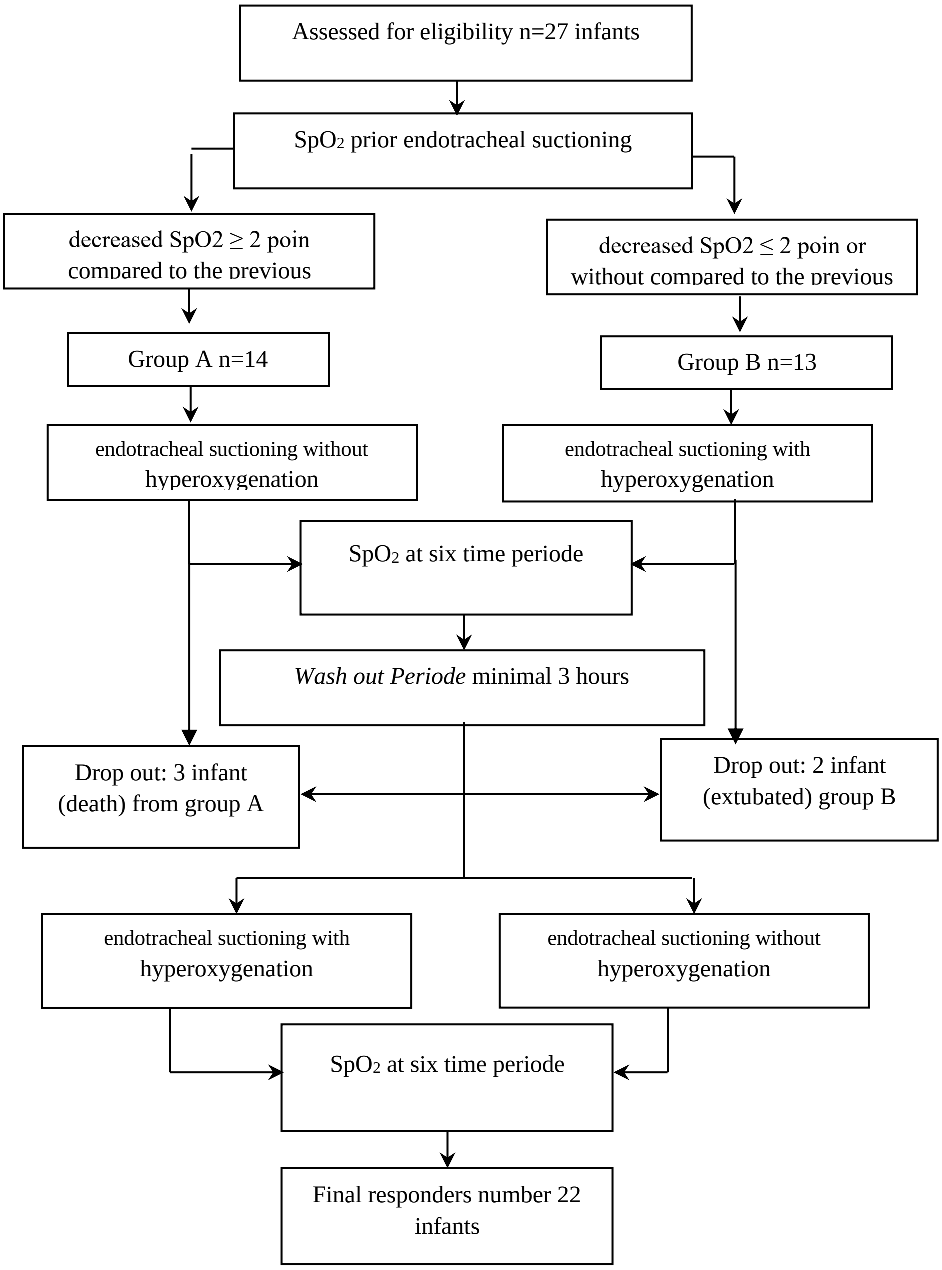

Figure 1. Recruitment Diagram and Respondent Allocation

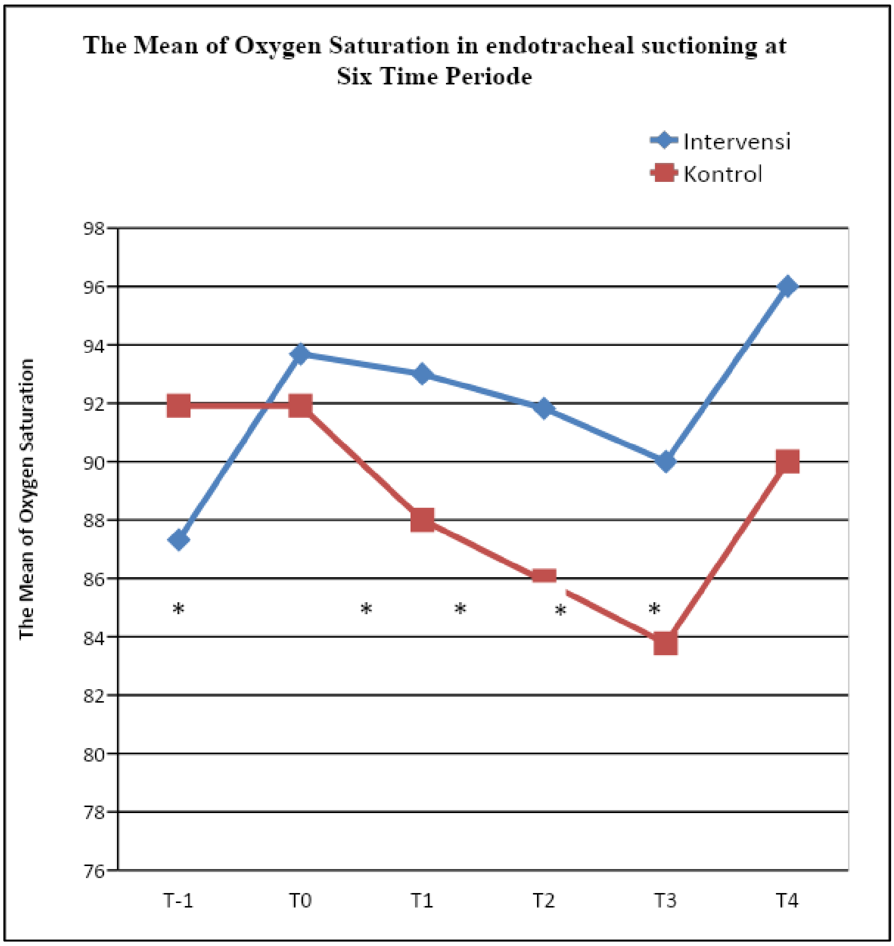

Figure 2. The Changes of Oxygen Saturation in Endotracheal suctioning at control and intervention group