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COMPARISON OF NONINVASIVE MECHANICAL VENTILATION AND NASAL CANNULA USE IN DEEP SEDATION PROCEDURES PERFORMED FOR DENTAL TREATMENTS OF CHILDREN*

ÇOCUKLARIN DİŞ TEDAVİLERİNDE YAPILAN DERİN SEDASYON İŞLEMLERİNDE NON-İNVAZİV MEKANİK VENTİLASYON VE NAZAL KANÜL KULLANIMININ KARŞILAŞTIRILMASI

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ABSTRACT

For deep sedation procedures, supplemental oxygen is usually administered via a nasal cannula to the patients. Non-invasive mechanical ventilation (NIMV) is the oxygenation method, especially used in the treatment of hypoxia. We aimed to compare the use of nasal cannula and NIMV applications via nasal mask methods for deep sedation procedures in the dental treatments of children, especially in terms of patient safety and the convenience of the dentist to apply the treatment. Patients were divided into two groups as the nasal mask group (M) and the nasal cannula group (N). For oxygenation, while a nasal cannula was used for group N, NIMV with a nasal mask was applied for group M. Hemodynamic parameters of the patients, complications and dentist's satisfaction degree were recorded and compared. Saturation of blood oxygen (SpO_2) was significantly higher in group M after induction of anesthesia and in the fifth minute of the procedure. Hypoxia ($SpO_2 \leq 90$) event number during the procedure was significantly higher in group N. Surgeon satisfaction was significantly higher in group M. We concluded that, in children undergoing deep sedation for dental treatments, NIMV applied with a nasal mask reduces the risk of hypoxia and is safer than using a nasal cannula.

Keywords: Deep sedation, dental treatment, nasal cannula, nasal mask, non-invasive mechanical ventilation.

ÖZ

Derin sedasyon prosedürlerinde, ek oksijen genellikle hastalara nazal kanül yoluyla verilir. Non-invaziv mekanik ventilasyon (NIMV), özellikle hipoksinin tedavisinde kullanılan oksijenasyon yöntemidir. Hasta güvenliği ve diş hekiminin tedaviyi uygulama kolaylığı açısından çocukların diş tedavilerinde derin sedasyon işlemlerinde oksijenasyon yöntemi olarak nazal kanül ve nazal maske ile NIMV uygulamalarının kullanımını karşılaştırmayı amaçladık. Hastalar nazal maske grubu (M) ve nazal kanül grubu (N) olarak iki gruba ayrıldı. Oksijenasyon için N grubu hastalara nazal kanül kullanılırken, M grubu hastalara nazal maske ile NIMV uygulandı. Hastaların hemodinamik parametreleri, görülen komplikasyonlar ve diş hekiminin memnuniyet derecesi kaydedildi ve karşılaştırıldı. Anestezi indüksiyonu sonrası ve işlemin beşinci dakikasında grup M'de kan oksijen saturasyonu (SpO_2) anlamlı olarak yüksekti. İşlem sırasında görülen hipoksi olayı ($SpO_2 \leq 90$) sayısı grup N'de anlamlı olarak daha yüksekti. Cerrah memnuniyeti grup M'de anlamlı olarak daha yüksekti. Çalışmamız ile; diş tedavileri için derin sedasyon uygulanan çocuklarda oksijenizasyonda burun maskesi ile uygulanan NIMV'nin hipoksi riskini azalttığı ve oksijenizasyonda nazal kanül kullanmaktan daha güvenli olduğu kanaatine varılmıştır.

Anahtar kelimeler: Derin sedasyon, diş tedavisi, nazal kanül, nazal maske, non-invaziv mekanik ventilasyon.

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INTRODUCTION

Dental treatment procedures in children may require anesthesia to provide immobility as well as to prevent fear and anxiety in children. Children are often presented to dentists for extensive dental treatment, which includes invasive and lengthy procedures. Comprehensive dental treatments in children can be performed under a general anesthesia procedure, in which immobility can be fully achieved. Complete immobility can also be provided by deep sedation procedures. These procedures, where the depth of anesthesia can be achieved at the level of general anesthesia, are more advantageous since they do not include invasive procedures such as laryngoscopy performed in general anesthesia. At the same time, there are some conditions that, although local anesthesia is sufficient, general anesthesia or deep sedation need may appear. Uncooperative patients with incomplete mental, physical, or psychological development, patients who still experience pain during the procedure despite the repeated application of local anesthesia, and patients who have an infection or abscess formation in the interventional region of a tooth can be chosen as examples of these conditions (1). Sedation procedures are an effective and humane way of facilitating dental care for young, anxious children and those with extensive treatment needs (2). Especially, deep sedation procedures are good ways to complete dental treatments safely, successfully, and comfortably.

In sedation procedures usually, sedative drugs are administered intravenously (IV) to achieve the desired depth of anesthesia and usually the necessity to deliver oxygen to the patient's respiratory system arises. Many sedative drugs cause a decrease in tidal volume and respiration rate by affecting the respiratory pattern, and this condition requires closer monitoring (3). Among the available sedative drugs, propofol is preferable for dental day-case anesthesia because of its beneficial effects on recovery time and postoperative nausea and vomiting (4,5). The oxygen delivery to the patient's respiratory system can be achieved through using nasal cannulas or interface masks (e.g., nasal masks) connected to the anesthesia machine.

This study hypothesized that during deep sedation procedures for dental treatments, oxygen delivery via NIMV application with using a nasal mask connected to the anesthesia-breathing circuit unit would be better than oxygen delivery via nasal cannula connected to the anesthesia machine. Thus, our primary aim was to compare NIMV and nasal cannula use in deep sedation procedures performed for dental treatments of children. The secondary aim of this study was to evaluate the degree of surgeon satisfaction in procedures in which nasal cannula was used and in procedures in which NIMV applicated with a nasal mask.

MATERIAL and METHODS

This prospective and randomized study was performed with the approval of the Local Ethics Committee of Erciyes University. After obtaining written consent from parents, seventy-three pediatric patients aged between 2 and 10 years and had American Society of Anesthesiologists (ASA) I status were included in this study. Patients with a known history of allergic reactions or additional chronic diseases were excluded. The patients were randomly divided into two groups using a coin-toss method. The study was approved by the local Ethics Committee of Erciyes University (03/10/2018, No: 2018/475).

All patients received EMLA (Eutectic Mixture of Local Anesthetics, AstraZeneca, London, UK) cream treatment before inserting a 24-G intravenous vascular access catheter unless contraindicated. The patients were premedicated using 0.05 mg/kg intravenous midazolam before they were taken to the operating room. Non-invasive standard monitoring for electrocardiography (ECG), heart rate (HR), blood pressure, and SpO_2 were used for all patients in the operating room. The values of hemodynamic parameters were recorded before and at every fifth minute of the procedure. Every patient was administered propofol at 2 mg/kg for the induction of anesthesia and adequate sedation. Adequacy of sedation was determined using the Ramsay Sedation Scale (RSS) score. The RSS score of 1 refers to patients who are nervous, agitated, and/or restless; 2 – to patients who are cooperative, oriented, and quiet; 3 – to patients who obey orders; 4 – to patients who are sleeping and who respond immediately to glabellar stimulation and a loud voice; 5 – -to patients who are sleeping and who respond slowly to glabellar stimulation and a loud voice; 6 – to patients who have no response to any stimulation. RSS values 5 or 6 were considered to be adequate sedation (6). Also, 0.5 mg/kg propofol was added if needed during the procedure. Local anesthetic solution (3-4 mL) of Ultracain D-S (Sanofi Aventis, Istanbul, Turkey) was administered to each tooth as needed. Patients whose dental treatments were to be performed under deep sedation were randomly divided into two groups as the nasal mask group (group M) and the nasal cannula group (group N). NIMV was applied to patients in group M via a nasal mask in the pressure control mode throughout the deep sedation procedure. To ensure sufficient tidal volume, the ventilator was set as follows: PEEP to 5 cm H_2O, inspiratory airway pressure to 15-20 cm H_2O, FiO_2 to 40%, respiratory rate to 15-20 breaths/min, and the inspiratory time to 1.6 seconds. In group N, oxygen was adjusted to give a rate of 4 L/min into both nostrils through a nasal cannula connected to the oxygen flowmeter of the machine.

The demographic data, the number of breaks due to the hypoxia (90% and lower SpO_2), surgeon satisfaction, and the total time off taken for recovery according to the modified Aldrete score were compared. The MAS system was used to check the availability for the discharge of patients with scores between 0-10 (7). Scores of 9 and above indicate that the patient can be discharged (Table I).

Hemodynamic parameters and RSS scores were recorded for every fifth minute. In addition, the total dose of propofol used for both groups, possible complications, e.g., allergies, coughing, gagging, and nausea and vomiting, were recorded. Surgeon satisfaction was categorized as good, moderate, and poor and recorded at the end of the surgery. Duration of surgery was categorized as 5-10 minutes and 10-15 minutes.

Table I. Items in the Modified Aldrete Score (7)

Item	Answer choices (points)
Consciousness	Fully awake - 2 Arousable on calling -1 Not responding - 0
Mobility	Able to move four extremities on command - 2 Able to move two extremities on command - 1 Able to move 0 extremities on command - 0
Breathing	Able to breathe deeply - 2 Dyspnea - 1 Apnea - 0
Circulation	Systemic BP ≠ 20% of the pre-anesthetic level - 2 Systemic BP between 20% and 49% of the pre-anesthetic level - 1 Systemic BP ≠ 50% of the pre-anesthetic level - 0
O2 saturation	Maintaining O_2 saturation >92% on room air - 2 Needs inhalation to maintain O_2 saturation >90% - 1 O2 saturation <90% despite O_2 supplementation - 0

This score checks whether patients can be discharged from the Post-Anesthesia Care Unit (PACU). The modified Aldrete score ranges from 0 to 10. Scores of 9 and above indicate that the patient can be discharged

Estimation of Sample Size

The published data on the impact of NIMV during deep sedation of anesthetized patients are limited. Therefore, a power analysis was performed based on a previous study, similar to our research when NIMV was evaluated in deep sedation (8). According to the power analysis, when the type 1 error was 0.05 and the test power was 0.90, the minimum number of patients required in each group was determined as 30.

Statistical Analyses

Data normality for continuous variables was evaluated using a histogram, q-q plots, and the Shapiro-Wilk test. For variables with normal distribution, the Levene test was performed to examine variance homogeneity. The differences between groups were compared using the independent samples t-test or the Mann-Whitney U test. For categorical variables, Fisher's exact test or the Chi-square test was performed. Data values were shown as mean±standard deviation, median (minimum-maximum), or frequency (percentages) values. Analyses were conducted using TURCOSA (Turcosa Analytics Ltd. Co., Turkey, www.turcosa.com.tr). A p-value of less than 0.05% was considered statistically significant.

RESULTS

A total of 73 patients were included in the study. The two groups were similar in demographic data, surgical time, propofol consumption, and total time for recovery according to MAS scores (Table II).

Table II. Patients' demographics data, amount of propofol consumption, anesthesia time, Modified Aldrete Scores, the incidence of hypoxia, and degree of surgeon satisfaction

	Group N (n=36)	Group M (n=37)	*p*-value
Age (years)	5.52± 2.19	5.54± 1.74	*0.97*
Weight (kg)	21.47±6.98	20.56± 6.17	*0.55*
Gender (M/F)	23/13	16/21	*0.14*
Propofol consumption (mg)	60.27 ± 22,35	60.27 ± 16.91	*0.99*
Duration of the anesthesia (minute)	5-10 (n=25) 10-15 (n=11)	5-10 (n=31) 10-15 (n=6)	*P>0.05*
Time until Modified Aldrete Score of 9 or higher (minute)	35 (31.38-39.69)	35 (31.38-39.69)	*P>0.05*
Incidence of hypoxia during the procedure	61.11% (n=22)	10.81% (n=4)	*< 0.001**
Surgeon satisfaction (%) *Good* *Moderate* *Poor*	 27.77% (n=10) 27.77% (n=10) 44.44% (n=16)	 91.89% (n=34) 8.10% (n=3) 0% (n=0)	*< 0.001**

Values were presented as mean±standard deviation or median (minimum-maximum) values, frequencies (percentages), and the number of patients. $p < 0.05$

The duration of anesthesia in 34.2% of patients from group N and 42.4% of patients from group M was 5-10 minutes. Baseline hemodynamic parameters were similar between the two groups. However, after propofol and at the 5th minute of the procedure, the saturation parameter was found to be higher in group M than in group N ($p<0.001$, Table III) (Figure I and Figure II).

Hypoxia was the only complication occurred during the procedure ($SpO_2<90$). The frequency of hypoxia was 61.11% in group N and 10.81% in group M. Surgeon satisfaction was significantly higher in group M than in group N because of the lower number of interruptions during the procedure. In group N, the rate of surgeon satisfaction recorded as 'good' was 27.7%, whereas this rate was 91.89% in group M. In group M, no surgeon graded their satisfaction as 'poor' (Table II) (Figure III).

Table III. Patients' hemodynamic parameters and RSS scores

	Oxygen Saturation %	Heart Rate (beat/min)	Systolic Blood Pressure (mm Hg)	RSS Score
Group N (n=36)				
Before the anesthesia	98 (97.51-98.63)	108.51±20.70	106.25±10.73	2 (1.59-2.06)
After the Propofol	93 (90.09-94.84) *	115±15.82	104.33±12.19	4 (3.59-4.40)
5th minute of the procedure	96 (91.65-96.07) *	111.42±17.06	104.75±11.72	5 (4.05-4.72)
Group M(n=37)				
Before the anesthesia	98 (97.96-98.73)	109.66±20.75	113.78±11.64	2 (1.37-1.70)
After the propofol	99 (97.99-99.19) *	102.54±17.34	106.62±13.33	5 (4.48-5.03)
5th minute of the procedure	100 (98.60-99.50) *	109.32±16.43	108.83±12.49	5 (4.91-4.51)

Values were presented as mean±standard deviation or median (minimum-maximum) values* = $p < 0.05$
Ramsay Sedation Scale(RSS)

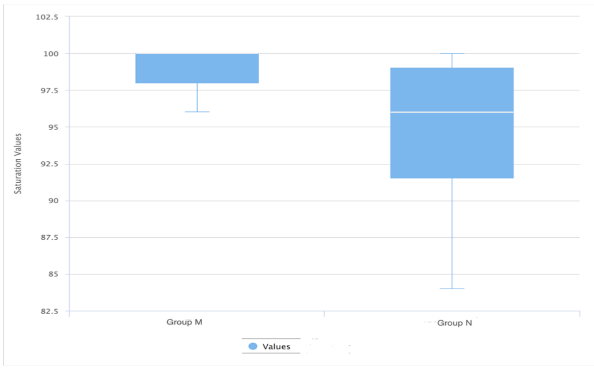

Figure I. Oxygen saturation values of patients after administration of propofol.

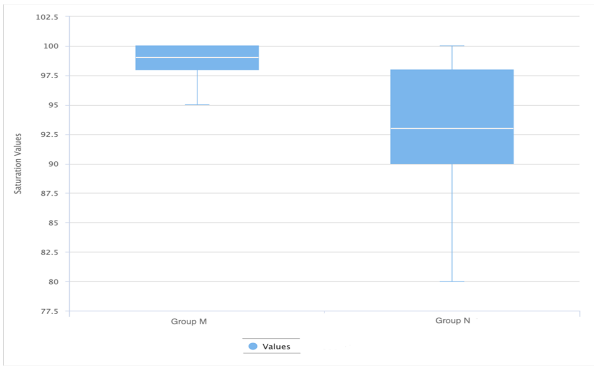

Figure II. Oxygen saturation values of patients at the 5th minute of the procedure.

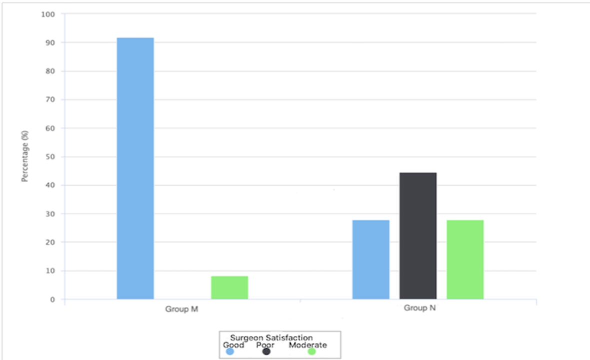

Figure III. Grades of Surgeon satisfaction rates recorded as 'good,' 'moderate,' and 'poor.' In group M, no surgeon graded their satisfaction as 'poor.'

DISCUSSION

Sedation in children and adults varies in some respects. Mainly the purpose of sedation is to provide analgesia and reduce anxiety for adults. However, one of the primary purposes of sedation for children is to provide immobilization because immobility increases the success of most treatments, including dental procedures, and prevents undesirable complications. Some examples of unwanted complications for dental treatments where immobilization cannot be provided would be infiltration of a local anesthetic to the wrong area or breaking a tooth or tooth root during extraction. For the success of procedures that required immobility, especially for children younger than six or children with developmental delay, the deep sedation requirement was highlighted in previous studies (9-11).

Any agent used for sedation may cause adverse effects on upper airway patency, ventilatory function, or the cardiovascular system. These effects can be seen more, especially in deep sedation procedures. All sedative drugs, except dexmedetomidine, are known to have a seriously depressing effect on respiratory functions in sedative dose ranges (12). For this reason, the practitioner should know the pharmacology of sedative drugs and the impact on the respiratory and cardiovascular functions of the most used sedation agents (13).

Among the available sedative drugs, propofol is preferable for dental day-case anesthesia because of its antiemetic feature and its beneficial effects on recovery time (4,5). The reasons for choosing propofol can be listed as rapid clearance feature from the central compartment after the last intravenous administration, its conversion to inactive metabolites feature by the liver rapidly, and its excretion feature with urine. Especially the rapid separation feature from the central compartment provides a short recovery time, which makes it preferable (13). This situation allows the early discharge of patients in centers, such as our center, where ambulatory anesthesia procedures are performed.

Pratila et al. (14) compared propofol and midazolam as a clinical study in sedation procedures, and they denoted that amnesia was provided very well with midazolam. In contrast, postoperative recovery was achieved faster with propofol. Another propofol-midazolam comparative study of Yamakage et al. (3) in sedation procedures stated that the respiratory effects of propofol were more pronounced, especially during sedation. We obtained enough depth of anesthesia with propofol due to the application of local anesthesia, and we did not need any additional sedative medication usage in our study.

Studies have revealed that children under six years of age are at a high risk of adverse effects of sedation, and this age group is particularly sensitive to the effects of sedatives on airway patency and protective airway reflexes (15-17). In this age group, anesthetic drugs have more effects on respiratory drive, protective airway reflexes, and airway patency than adults (16,17). As the depth of anesthesia increases, airway obstruction tends to increase, especially in the upper airway; this condition is called ''anesthesia-induced airway obstruction.'' Children are more prone to anesthesia-induced airway obstruction when compared to adults because Aden tonsillar hypertrophy is seen more widely in children (18-20). Also, studies suggest that children more easily pass from an intended sedation level to a deeper, unacceptable level of sedation, and this situation leads to more risk of airway obstruction and respiratory depression (12,21,22).

Delivering oxygen to the respiratory system of a patient is vital in sedation procedures. Oxygenation options in deep sedation, respectively, include using a nasal cannula or face masks, followed by NIMV application, and followed by intubation or mechanical ventilation application if a case of respiratory failure occurs. Oxygenation via nasal cannula or nasal mask without NIMV necessitates more closely monitoring. Up to 15 L/min flow rates can be achieved with a nasal cannula. However, these flow rates may be significantly lower than patients' spontaneous inspiratory flow rates because the oxygen is diluted by room air. Consequently, the proportion of inspired oxygen becomes variable (14).

While care should be taken at all levels of sedation, deep sedation needs more careful monitoring because the level of deep sedation may pass to the next stage, which is known as general anesthesia. In this event, the risk of hypoxia and hypercapnia, and the need for invasive procedures, such as laryngoscopy, can increase (19). As we have experienced in our study, NIMV is a good option for preventing such conditions.

As known, general anesthesia applications are more invasive than sedation procedures. Sedation procedures need more close monitoring because of the risk of respiratory depression and, in this way, the occurrence of desaturation. Elimination of the need to administer muscle relaxants and invasive procedures like laryngoscopy to patients, its property of lower postoperative morbidity, and by this way earlier discharge of patients are significant advantages of sedation procedures with NIMV.

We encountered only a few studies where the effectiveness of NIMV for the oxygenation of patients during deep sedation was evaluated. One of them was a study performed in the lower extremity and abdominal surgeries. In this study, it was emphasized that NIMV provided safe anesthesia without the need for invasive procedures, such as laryngoscopy, at the desired depth of anesthesia (23). In a study by Suresh et al. (24), patients were divided into three groups. NIMV was applied via a nasal mask to the control group at 0 cm H20 CPAP, which is the same manner as the oxygen application method given via nasal cannula, at 2.5 or 5 cm H2O of CPAP to other groups. They found a significant difference between groups concerning oxygen desaturation. The incidence and severity of desaturation were less prevalent in the NIMV group applied at 5 cm H_2O when compared to the control group.

In a study by Sbrana et al. (8), oxygenation methods were compared in deep sedation procedures, and it was concluded that, as in our study, NIMV was a safer method. In another study by Maruthu et al. (22), it was reported that the airway obstruction status, which occurred at the level of the soft palate due to propofol anesthesia, could be dealt with the way of NIMV application. In the same study, the investigators used the continuous positive airway pressure (CPAP) mode, a ventilation mode similar to that used in our research, with the nasal mask, and they concluded that this approach could provide airway continuity while preserving the airway patency.

The pressure control mode is commonly used in pediatric anesthesia practice. In this ventilation mode, after the inspiratory pressure, inspiratory time, and breathing rate are set, the ventilator supplies constant pressure during the entire inspiratory phase. In this mode, the pressure required to overcome the airway resistance is quickly produced with a high inspiratory flow to provide, even in the presence of small leaks, the desired tidal volume. Another of the advantages is the barotrauma preventive feature because its maximum inspiratory pressure is limited. Using this mode in deep sedation procedures with NIMV ensures continuity of breathing in case of apnea (25). Furthermore, this detail was the starting point of our study.

In our study, we also believed that deep sedation would allow the surgeon to work comfortably and ultimately achieve the success of the treatment; to avoid the risk of hypoxia and hypercapnia, we have used NIMV.
We experienced desaturation events (90% and lower SpO2) in only four of 37 patients, which we believe was due to technical reasons (e.g., the poor fit of the interface mask). However, we experienced a desaturation event in 22 of the 36 patients in the nasal cannula group, which required immediate intervention and interruption of surgical procedures. We applied a manual bag mask-ventilation procedure by increasing the oxygen flow in children who developed desaturation.
For many reasons mentioned above, many children require general anesthesia or deep sedation in dental treatments. We recommend that pediatric dentists and anesthesiologists should have information about noninvasive mechanical ventilation applications with a nasal mask, which is as comfortable and safe as general anesthesia in deep sedation procedures.
The limitation of this study is that end-tidal carbon dioxide values were not included as we were unable to measure end-tidal carbon dioxide with a nasal cannula.

CONCLUSION

The present study demonstrated that deep sedation procedures were conducted more safely with NIMV applied via nasal cannula use. Because of seen significantly low rates of hypoxia and fewer procedural interruptions with NIMV application.
As a result, we conclude that in deep sedation procedures for the dental treatments of children, NIMV application with a nasal mask is safer and more suitable than procedures conducted with nasal cannula use. More studies are required for sedation procedures and NIMV.

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Main Points

1. Deep sedation procedures are very comfortable for the patient and surgeon, but the risk of apnea increases as the level of sedation increases. With NIMV, this risk can be eliminated, thereby eliminating the risk that patients are exposed to invasive procedures such as laryngoscopy**.**
2. Dentists should also be informed that most dental procedures can be performed with deep sedation instead of general anesthesia and that using NIMV in these procedures will be beneficial for patient safety.
3. In dental procedures that require general anesthesia, complications in the postoperative period due to intubation, such as sore throat and similar, can be prevented by NIMV application through a nasal mask.

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