A comparison of intra cuff pressures in high-flow and low-flow nitrous oxide anesthesia

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ABSTRACT

الأهداف: فحص تغيرات الضغط داخل الكفة في التيار المنخفض (LFA) والتيار المرتفع (HFA) للتخدير بأكسيد النتروجين (N_2O) خلال الفترة المتوسطة للإجراءات الجراحية.

الطريقة: تمت هذه الدراسة الوصفية العشوائية المفردة بمستشفى نعمان التعليمي ومركز الأبحاث – أنقرة – تركيا، خلال الفترة ما بين يناير 2005م وحتى ديسمبر 2005م. تم إدراج سبعين مريضاً تراوحت أعمارهم ما بين 18–65 عاماً، من الدرجة I–III حسب مقياس الجمعية الأمريكية لأطباء التخدير، والذين يخضعون لعملية جراحية اختيارية في هذه الدراسة. عقب التحريض المعياري تم إجراء التخدير الاختياري بعقار آسوفلوران (نهاية المد 1%–0.9) في (4L/minute) أو (one L/minute) من تيار الغاز الجديد في مجموعتي التيار المرتفع (HFA) والتيار والمنخفض (LFA) على التوالي. تم قياس الضغط في الكفة باستمرار باستعمال مقياس ضغط الغازات السائلة، والأكسجين المستنشق، وملاحظة مستويات أكسيد النتروجين (N_2O) كل 10 دقائق خلال الدراسة.

النتائج: لم يكن هنالك فرقاً بين مجموعتي التيار المرتفع (HFA) والمنخفض (LFA) لضغـــط الكفة الأولي
.(mean±SD, HFA=20.9±4.19, LFA=20.4±4.11, cmH_2O)
وضغط الكفة المرتفع (MCP)
(mean±SD, HFA=32.3±18.74, LFA=33.5±8.89, cmH_2O)
($p>0.05$). كان وقت الوصول إلى الضغط الأقصى داخل الكفة اقصر بشكل ملحوظ في مجموعة التيار المنخفض عنه في مجموعة التيار المرتفع 89.3±23.94minutes - 77.4±20.33minutes على التوالي ($p=0.038$). بين الدقيقة العاشرة والدقيقة التسعون، وكانت مستويات استنشاق الأكسجين أعلى بشكل ملحوظ لدى مجموعة التيار المرتفع ($p=0.001$). بينما كان استنشاق أكسيد النتروجين (N_2O) أعلى لدى مجموعة التيار المنخفض ($p=0.001$).

خاتمة: يجب قياس مستوى ضغط داخل الكفة بدقة خلال فترة التيار المنخفض (LFA)، حيث إن مدة الوصول لأقصى ضغط داخل الكفة كانت أقصر منها في التيار مرتفع (HFA).

Objectives: To investigate intra cuff pressure changes in low-flow anesthesia (LFA) and high-flow (HFA) N_2O anesthesia during moderate-duration surgical procedures.

Methods: We carried out this prospective, randomized, single blind study at Numune Educational and Research Hospital, Ankara, Turkey between January to December 2005. Seventy patients aged between 18-65 years, American Society of Anesthesiologists (ASA) physical status grades I-III, undergoing elective surgery were enrolled in this study. Following a standardized induction, anesthesia was maintained with isoflurane (end-tidal 0.9-1%) at 4 L/minute for the HFA group, or 1 L/minute for the LFA group fresh gas flows. Endotracheal tube cuff (intra cuff) pressures were measured continuously with a pressure manometer, and inspired oxygen and N_2O levels were noted every 10 minutes throughout the study.

Results: There was no significant difference between HFA and LFA groups for initial (first) cuff pressures (mean±SD, HFA=20.9±4.19, LFA=20.4±4.11, cmH_2O), and maximum cuff pressures (MCP) (mean±SD, HFA=32.3±18.74, LFA=33.5±8.89, cmH_2O) ($p>0.05$). The time to reach the maximum intra cuff pressure was significantly shorter in the LFA group (77.4±20.33 minutes), than the HFA group (89.3±23.94 minutes), ($p=0.038$). Between the tenth and nineteenth minutes, inspired oxygen level was significantly higher in the HFA group ($p=0.001$), whereas inspired N_2O was significantly higher in the LFA group ($p=0.001$).

Conclusion: The intra cuff pressures should be monitored carefully during LFA, since the duration to reach the maximum intra cuff pressures was shorter than that of HFA.

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Nitrous oxide (N_2O) is 35 times more soluble in blood than nitrogen. Therefore, it diffuses from blood into the air-containing spaces, such as endotracheal tube (ETT) cuff more rapidly than nitrogen.[1] Endotracheal tube cuff volume and pressure increase through N_2O diffusion into the cuff during general anesthesia.[2-6] If the ETT cuff pressure is not below the mean mucosal capillary perfusion pressure, various tracheal injuries such as mucosal erythema and/or edema, and erosion, and/or hemorrhage on the anterior and posterior tracheal walls may occur, depending on the amount and duration of the excessive pressure.[6,7] Low-flow anesthesia is an anesthetic technique, in which a semi-closed rebreathing system is used recirculating at least 50% of the exhaled air, and fresh gas flow is restricted in 1 L/minute.[8] Since N_2O uptake slows down after initiation period in the low-flow N_2O anesthesia, inspired N_2O fraction (FiN_2O) increases if the flow of N_2O is greater than N_2O uptake from the breathing system.[1,8] To our knowledge, there are no reports on intra cuff pressure changes in the low-flow anesthesia (LFA) technique, although numerous studies have investigated the relationship between the use of N_2O and ETT cuff changes in high flow anesthesia (HFA).[3-7,9,14-16] The aim of this study was to investigate the ETT cuff pressures in relation to the concentrations of the inspired N_2O in LFA, and to compare the results with the ETT cuff pressures in HFA.

Methods. After obtaining the approval from the Ankara Numune Educational and Research Hospital's Ethics Committee and informed patient consents, 70 patients (ASA physical status I-III, aged between 18 and 65 years) undergoing elective surgery between January to December 2005 were randomly enrolled to the single-blind, prospective study. The patients did not have a known tracheal or laryngeal disorder, they were not undergoing a head and neck surgery and the expected duration of the operation was between 60-180 minutes. Patients were excluded from the study if an alteration had to be made in the N_2O concentration during surgery, like there were signs of bronchospasm, when the intubation was difficult (the ones intubated after 2 or more attempts), or the duration of the operation was <60 minutes or >180 minutes. Patients were randomly allocated into 2 groups (randomization was performed by drawing the allocation group code from a sealed envelope). Group HFA (n=31) received 4 L/minute, and group LFA (n=31) received 1L/minute fresh gas flow. All patients were premedicated with 10 mg diazepam by mouth the night before the operation. Clinical monitoring was provided by Drager Datex Ohmeda S/5 (Bromma, Sweden) anesthetic machine that included electrocardiogram, pulse oximetry, non-invasive arterial pressure, nasopharyngeal core temperature, capnography, inspired and expired oxygen levels, nitrous oxide, and volatile agent, and airway pressures, tidal volume, ventilatory frequency, and minute volume.

All patients were pre-oxygenated with 100% oxygen for 3 minutes before the anesthesia induction. Anesthesia was induced with propofol (2-3 mg/kg), and fentanyl (2 µg/kg), and muscle relaxation was accomplished with vecuronium (0.1 mg/kg). The patients were intubated following the mask ventilation for 3 minutes. Tracheal intubation was performed with polyvinyl chloride high-volume, low-pressure cuffed tracheal tubes (Portex Blue Line; Portex Ltd, Hythe, UK) in both groups. We used 7.5-8 mm internal diameter (ID) tracheal tubes for females, and 9-9.5 mm ID tracheal tubes for males. Immediately after intubation, the ETT cuff was inflated with air just sufficient enough to prevent a tracheal gas leak at an end-inspiratory plateau pressure of 20 cm H_2O in both groups. Thereafter, the pilot balloon of ETT was continuously connected to a pressure manometer (Rüsch, Endotest for low pressure cuffs), and the first pressure (initial cuff pressure, ICP) value was noted. If the first pressure value exceeded 30 cm H_2O, the cuff was deflated via manometer until the pressure decreased to 20-25 cm H_2O without air leak. Throughout the study, the cuff pressures were measured continuously, and recorded every 10 minutes in the expiration phase of the ventilation by an observer blinded to the groups. Anesthesia was maintained with isoflurane (end-tidal 0.9-1%), and an initial high fresh gas flow (4 L/minute, 40% O_2+60% N_2O) lasted 10 minutes in both groups, to allow for initial rapid uptake of N_2O and elimination of nitrogen.[8] After 10 minutes, high fresh gas flow (4 L/min, 50 % O_2+50% N_2O) was continued to be applied in HFA group whereas low gas flow (1 L/minute, 50% O_2 + 50% N_2O) was started to be applied in LFA group. Inspired levels of oxygen and N_2O, and $ETCO_2$, SpO_2 were recorded every 10 minutes. Before tracheal extubation, the patient breathed 100% oxygen in 4 L/minute flow for 5 minutes. Neuromuscular blockage was reversed with 0.04 mg/kg neostigmine + 0.02 mg/kg minute atropine at the end of study. Following the extubation in expiration phase of ventilation, all cases were taken to the recovery room.

Statistical analysis. Data were analyzed using SPSS version 11.5. The values were presented as the mean±SD in the text and the tables. The $p<0.05$ were considered as statistically significant. The means of the 2 groups for cuff pressures and the time to reach the maximum cuff pressures were compared using one-way analysis of variance test. Dependent t-tests were used in each group to compare the mean values for FiO_2 and FiN_2O as pairs at definite time points (0, 10th up to the 120th minutes). The sample size of the study was determined on the basis of the samples sizes of the previous studies.[4,7] The measurements were analyzed statistically. One of those analyses was the investigation of the difference between the mean of the times to reach the maximum cuff pressures. Analysis of variance was used for this purpose. The results of this analysis had demonstrated a power of 83.7% for 2 independent groups with 31 patients [σ (SD)=22.20, Δ (delta)=11.93, 2-tailed alpha=0.05].

Results. Eight patients were excluded from the study; one due to bronchospasm (post-intubation), 2 for a change in the ratio of N_2O/O_2 administered, 3 because of surgical durations <1 hour, one because of surgical duration more than 180 min, and one because the first value of intra cuff pressure was more than 35 cm H_2O. The ages, gender, duration of anesthesia, were similar in 2 groups ($p>0.05$, **Table 1**). There was no significant difference between the initial cuff pressures (ICP) [(mean±SD), HFA=20.9±4.19, LFA=20.4±4.11 cmH_2O, ($p>0.05$)], and maximum cuff pressures (MCP) of the 2 groups [(mean±SD), HFA=32.3±18.74, LFA=33.5±8.89 cmH_2O] (**Figure 1**). The time to reach the maximum intra cuff pressure (TRMCP) was significantly shorter in the LFA group (77.4±20.33 minutes) than the HFA group (89.3±23.94 minutes, $p=0.038$, **Table 1**). Between the 10th and 90th minutes, FiO_2 was significantly higher in HFA group ($p=0.001$), whereas FiN_2O was significantly higher in LFA group ($p=0.001$, **Figure 2**).

Discussion. Comparison of ETT cuff pressures in LFA and HFA N_2O anesthesia in this study showed, that intra cuff pressure is increased in both groups with diffusion of N_2O into the cuff independent of flow rate. But this increase was within acceptable limits, and time to reach MCP was shorter in LFA group. The ETT cuff must avoid the air leak to permit maintenance of airway positive pressure, and prevent aspiration of pharyngeal contents.[7] In routine clinical practice, ETT cuffs are usually inflated with room air, and they constitute an air-filled space in the body, and as a result N_2O diffuses into the cuff.[10] The amount of volume increase depends on inspired N_2O (FiN_2O), cuff compliance, inflation volume, and gradient of N_2O between ETT cuff and inspired gas, whereas the rate of volume increase depends

Table 1 - Demographic data and cuff pressures in each group.

Groups (n=31)	Age (year)	Gender (F/M)	ICP (cmH_2O)	MCP (cmH_2O)	TRMCP (min)	Duration of anesthesia (min)
High flow anesthesia group	50 ± 15	13/18	20.9 ± 4.19	32.3 ± 18.74	89.3 ± 23.94	113.5 ± 25.20
Low flow anesthesia group	48 ± 14	15/16	20.4 ± 4.11	33.5 ± 8.89	77.4 ± 20.33*	115.4 ± 23.73

Data are presented as mean and standard deviations (SD). ICP - initial cuff pressure, MCP - maximum cuff pressure, TRMCP - time to reach to maximum cuff pressure, *$p=0.038$ versus high flow anesthesia group

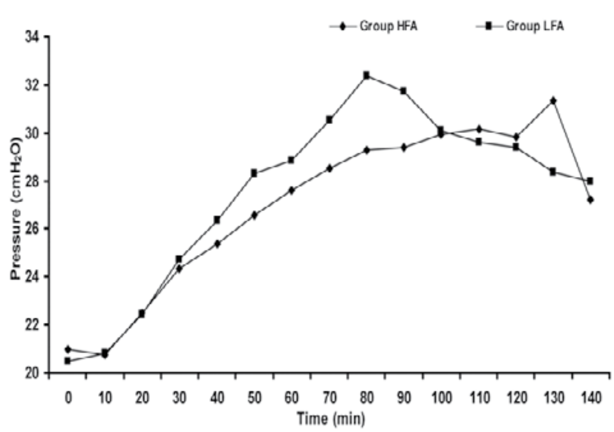

Figure 1 - The intra cuff pressures of high flow anesthesia (HFA) group and LFA groups over time.

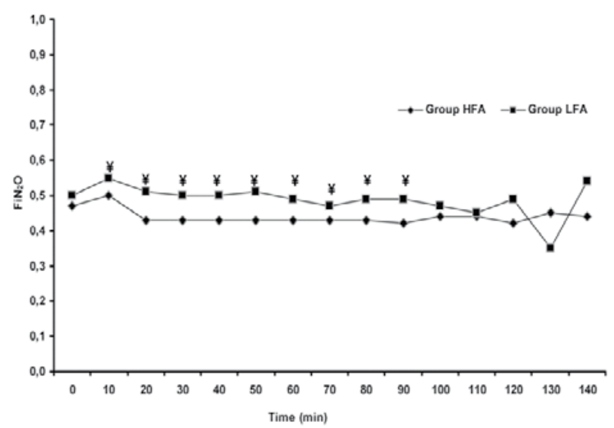

Figure 2 - Time-related inspired N_2O fraction (FiN_2O) % values of each group.

on the diffusion coefficient of cuff material to N_2O.[2,5] The capillary perfusion pressure of the tracheal mucosa is 20-35 mm Hg.[2,3,11,12] Human studies have shown that intra cuff pressures, greater than 40 mm Hg (54.3 cmH_2O) produce ischemic changes on the tracheal wall within 15 minutes.[13] In our study, intra cuff pressures did not increase to the critical levels in either group, however, it must be considered that the intra cuff pressures may increase by time. In the absence of routine ETT cuff pressure monitoring, the anesthesiologist must take precautions to avoid detrimental increases in cuff pressure during N_2O anesthesia. Various devices and techniques have been used for this purpose.[2,4,9,13-16] However, many of them are neither practical nor economic. Endotracheal tube cuff pressure monitoring during N_2O anesthesia seems to be the most reliable and economic method to avoid detrimental effects of increased cuff pressure.

Low-flow anesthesia has drawn the interest of anesthesiologists after the introduction of new inhalation anesthetics, modern anesthesia machines, anesthetics gas monitoring devices, and due to economic and ecological considerations.[8] One of the advantages of LFA is a better gas climatization, due to increased rebreathing. Humidification and heating of the gases provides preservation of the mucociliary clearance and the reduction of both microatelectasis and postoperative pulmonary complications.[17,18] Recently, LFA technique has been popular in our department. Since N_2O uptake slows down after initiation period of LFA, FiN_2O increases if the delivered N_2O amount is greater than its uptake.[1,8] Although the N_2O uptake reduces exponentially, O_2 uptake stays stable in definite limits. Thereafter, O_2 concentration in exhaled gas mixture decreases while N_2O concentration increases in time.[8,19] In the present study, the concentration of FiN_2O was significantly higher in LFA group than the HFA group, as expected. The difference persisted between the 10th and 90th minutes, however we did not find any significant difference after 90 minutes. This may be due to the variations in the duration of anesthesia (data are not statistically significant), or due to the use of a high flow in LFA group, 5 minutes before the end of the surgery. There was no significant difference between the groups for maximum cuff pressures. The airway irritation symptoms were not been asked in the patients during the postoperative period, and this is the limitation of our study, although this could be subject of future investigations.

In conclusion, shorter time to reach maximum cuff pressures in LFA group necessitates a more careful monitoring of the cuff pressures, and an increased level of alertness for an increased cuff pressure during LFA.

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