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MEDIUM-FLOW OXYGENATION THROUGH FACIAL MASK AND NASAL CANNULA IN A LIMITED RESOURCE SETTING

Aleksandra Gavrilovska-Brzanov[1], Mirjana Shosholcheva[2], Andrijan Kartalov[1], Marija Jovanovski-Srceva[1], Nikola Brzanov[1], Biljana Kuzamanovska[1]

[1] University Clinic for Traumatology, Orthopedic Disease, Anesthesiology, Reanimation and Intensive Care Medicine and Emergency Department, Faculty of Medicine, Ss. Cyril and Methodius University, Skopje, RN Macedonia

[2] University Clinic for General Surgery "St. NaumOhridski" Faculty of Medicine, University "Ss. Cyril and Methodius", Skopje, RN Macedonia

Corresponding author: Aleksandra Gavrilovska-Brzanov MD., MSc., PhD, Postal code: Bul. Jane Sandanski 84-3/14, 1000 Skopje, Phone: 0038971240701,Email: gavrilovska.aleksandra@gmail.com

ABSTRACT

Introduction: In centers with limited resources, a high flow nasal cannula is not available, thus we assess if preoxygenation with 15L flow of O2 available from anesthesia machines can prolong the safety period of induction of anesthesia before intubation and provide more time for securing the airway. Moreover, we compared the preoxygenation with standard 6L vs. 15L O2 through a facemask or a nasal cannula.

Material and methods: Patients were allocated into four groups. Group I patients were preoxygenated with a nasal cannula on 6L of oxygen, patients in group II were preoxygenated with a nasal cannula on 15L of oxygen, patients in group III were preoxygenated with a facemask on 6L of oxygen, and patients in group IV were preoxygenated with a facemask on 15L of oxygen. The primary endpoint was time to desaturation and intubation. The secondary endpoints were PaO2, PaCO2, Sat% and ETCO2.

Results: The groups with 15L preoxygenation had a statistically significant prolonged time to desaturation and intubation. Patients allocated to group II have a statistically significant greater PaO2 and lesser ETCO2 compered with group I. However, between patients in group III and IV there is a difference only in PaCO2, and although this effect is significant, both groups have values within the normal range.

Conclusion: In centers with limited resources, preoxygenation with the maximum available oxygen flow from anesthesia machines (15L/min) are useful. This prolongs the safety period for securing the airway. We suggest the use of the maximum available amount of oxygen flow from anesthesia machines in clinical settings.

Keywords: preoxygenation, oxygen flow, endotracheal intubation, nasal cannula oxygenation, facemask oxygenation

INTRODUCTION

The standard routine before induction in anesthesia is preoxygenation via a facial mask. Thus the apnea period is extended, and this usually prolongs the time enough so that the airway can be safely secured. [1, 2] Moreover, in difficult mask ventilation/intubation scenarios, hypoxemia of more than 6 minutes without mask ventilation may be fatal for the patient. [3] Delivery of supplemental oxygen in the airway in the absence of ventilation is apneic oxygenation.

[4] In order to avoid such life-threatening events, optimal preoxygenation and apneic oxygenation protocol are essential. This procedure can safely prolong the apnea interval during the induction of general anesthesia. [5]

Currently, delivering oxygen through a high flow nasal cannula (HFNC) is being increasingly used in different clinical settings, and it is supposedly beneficial in preventing hypoxemia. [6–8] However, HFNC is a novel respiratory strategy treatment that delivers 50-60L/min of warm, humidified air and many centers with limited resources do not have the appropriate equipment. [6–10] In centers with limited resources, oxygen delivery at 6L/min via nasal cannula or a facial mask is being used as a standard preoxygenation method. Moreover, the maximum available O2 (15L/min) from anesthesia machines is not so frequently used. [1]

Aim

To evaluate if preoxygenation and apneic oxygenation with the maximum available flow of 15L O2 from anesthesia machines in centers with limited resources can prolong the period of adequate oxygenation. Another aim is to compare the effectiveness between medium flow 15L/min nasal oxygenation with the standard 6L/min of nasal oxygenation vs. medium flow 15L/min facial mask oxygenation with the standard 6L/min of facial mask oxygenation.

MATERIALS AND METHODS

Data sources

After the internal ethics committee approval was obtained, this prospective randomized evaluation was conducted in the tertiary University Clinical Hospital "Mother Theresa" Skopje, at the Department of anesthesia, reanimation, and intensive care and at the Urology department. Sixty patients in total were enrolled. Included in this study were all patients who underwent scheduled elective urological surgery under general endotracheal anesthesia, ASA (American Society of Anesthesiologists) I/II, aged between 18 to 75 years, without presence of predicting factors for difficult intubation. To each participant we explained the study protocol before obtaining written informed consent for their participation in this study. Excluded from the study were all patients with any known history of respiratory disease, pregnant patients, transplanted patients, intubated patients, patients with anticipated difficult ventilation and intubation, patients with severe cardiovascular or cerebrovascular disease, patients with severe psychiatric disorders and patients who refused to participate in this study.

Design

In this study, patients were allocated into four groups according to a computer-generated table of randomization. According to patient group allocation, a different method of preoxygenation was conducted. The four groups were as follows: Group I were preoxygenated with nasal cannula on 6L of oxygen, patients in group II were preoxygenated with nasal cannula on 15L of oxygen, patients in group III were preoxygenated with facemask on 6L of oxygen, and patients in group IV were preoxygenated with facemask on 15L of oxygen..

Protocol

In the operation room, according to institutional protocol, before the induction of anesthesia to all patients, standard anesthesia monitoring was put in place. These are as follows: electrocardiography, non-invasive blood pressure monitoring, and pulse oximetry. All patients eligible for enrolment in the study were randomly assigned to one of the four groups. The clinical team decided for general anesthetic injection management and the neuromuscular blocking agent rocuronium bromide was the agent of choice in all patients. The arterial line for obtaining arterial blood gas analysis was placed before the induction in anesthesia. Difficult airway management equipment was available at all time. The facial mask size and nasal airway were chosen to fit the patients' individual faces.

In group I (n=15), patients were preoxygenated with a 6L flow of fresh oxygen for 3 minutes on spontaneous breathing through a tightly held face mask (to avoid air leaks), connected to anesthesia machine. Following the induction of general anesthesia, a nasal cannula was inserted, and a continuous positive airway pressure (CPAP) of 5cmH2O was set. Apneic oxygenation continued with 6L flow of oxygen.

In group II (n=15), patients were preoxygenated with a 15L flow of fresh oxygen for 3

minutes on spontaneous breathing through a tightly held face mask, connected to an anesthesia machine. Following the induction of general anesthesia, a nasal cannula was inserted and a CPAP of 5cmH2O was set. Apneic oxygenation continued with a 15L flow of oxygen.

In group III (n=15), patients were preoxygenated with a 6L flow of fresh oxygen for 3 minutes on spontaneous breathing through a tightly held facial mask, connected to anesthesia machine. Following the induction of anesthesia, apneic oxygenation remained through a tightly held facial mask, connected to an anesthesia machine on a 6L flow of oxygen.

In group IV (n=15), patients were preoxygenated with a 15L flow of fresh oxygen for 3 minutes on spontaneous breathing through a tightly held facial mask, connected to an anesthesia machine. Following the induction of anesthesia, apneic oxygenation remained through a tightly held facial mask, connected to anesthesia machine on a 15L flow of oxygen.

The total time protocol was 10 minutes. In the meantime, if patients desaturated to 91-92%, they were intubated. If desaturation did not occur after 10 minutes of apnea, patients were intubated and MV was started. Patients in the facial mask group were intubated without supplemental oxygen during laryngoscopy. While the patients in the nasal airway group, oxygenation was maintained until intubation was complete. Members of the medical team were aware of group assignment after enrolment. Independent observers, however, not involved in the performance of the procedure to collect the data. Observers were unaware of the group allocation of the patients as well.

Investigated parameters

We measured pulse oximetry saturation (Sa02%) at three time points: before preoxygenation, after preoxygenation before induction in anesthesia, and before intubation. Arterial blood gas analyses were obtained at two times: T1 after preoxygenation before induction in anesthesia and T2 after intubation. Immediately after intubation, end-tilde carbon dioxide (ETCO2) was noted as seen on the anesthesia monitor (Datex Ohmeda S5 Avance).

Outcome definitions

The primary endpoint was time to desaturation and intubation. The secondary endpoints were PaO2, PaCO2, SatO2% and ETCO2, measured at the end, after intubation of the patient.

Statistical analysis

A computer database was created. Analysis was performed with the IBM SPSS (20.0) program. Descriptive and analytical standard methods were used. Numerical variables were reported as median and ranges, and categorical variables were expressed in percentage. Statistical significance was indicated when p was <0.05. With multiple statistical testing, the p value of the mathematical value was corrected with the q value. For correction, we used a false discovery rate (FDR) method.

RESULTS

Demographic data are similar among groups. There are 19 female and 41 male included in this study (male/female ratios: group I 26/4, group II 24/6, group III 25/5, group IV 25/5). The patients were aged between 26 to 74 years. Prolonged apnea time is statistically significant (p=0.000) in groups with an oxygen flow of 15L/min, those being group II and group IV. The data are shown in table 1.

Pulse oximetry saturation (SaO2%) was measured at three time points: before preoxygenation, after preoxygenation before induction of anesthesia, and before intubation. Results show that patients preoxygenated with 15L/min of O2 had 1.001% higher oxygen saturation rates than patients preoxygenated with 6L/min at third time point. Using the interpretation of the q value, the results show no difference in the SaO2% among groups.

Graphics 1 and 2 show the results for ETCO2 after intubation in all groups. These results show that there is a difference in the ETCO2 level between group I and group II (p=o.0021). Patients in group II, who were preoxygenated with 15L on a nasal airway, have 6.4 mmHg-decreased ETCO2.

The results show no difference in the basal level (T1) of PaO2 among groups. Although, there are changes between nasal airway groups

Table 1. *Demographic data and apnea time.*

Vozrast	Min.	1st Qu.	Median	Mean	3rd Qu.	Max.	sd	p value	q value
Group I	45,000	59,000	61,000	60,933	66,000	69,000	6,330	0,062	0,150
Group II	26,000	45,500	51,000	52,800	64,000	74,000	14,561		
Group III	49,000	56,000	59,000	59,400	63,000	69,000	6,150	0,888	0.888
Group IV	43,000	56,000	60,000	59,067	63,000	69,000	6,724		
BMI	**Min.**	**1st Qu.**	**Median**	**Mean**	**3rd Qu.**	**Max.**	**sd**	**p value**	
Group I	20,000	22,600	23,500	23,393	24,600	25,000	1,533	0,113	0,239
Group II	22,500	23,250	24,500	24,167	25,000	25,500	0,976		
Group III	20,000	21,750	23,500	23,280	25,000	26,000	1,932	0,658	0,861
Group IV	20,500	22,250	23,000	23,000	23,750	25,500	1,464		
Vreme	**Min.**	**1st Qu.**	**Median**	**Mean**	**3rd Qu.**	**Max.**	**sd**	**p value**	
Group I	4,150	5,125	6,200	6,164	7,060	8,050	1,172	0,000	0,000
Group II	4,000	9,500	8,000	9,080	10,000	11,300	3,834		
Group III	2,000	2,775	3,450	3,491	4,010	6,150	1,066	0,000	0,000
Group IV	4,000	6,725	8,050	7,587	8,500	9,450	1,552		

Table 2. *Oxygen saturation (SaO%) in three time points.*

SaO_2% 1	Min.	1st Qu.	Median	Mean	3rd Qu.	Max.	sd	p value	q value
Group I	95	96	96	96,4	97	98	0,9856	1	1
Group II	94	96	96	96,4	97	100	1,5024		
Group III	95	95,5	96	96,2667	97	98	1,0328	0,7203	0,8693
Group IV	95	96	96	96,4	97	98	0,9856		
SaO_2% 2	**Min.**	**1st Qu.**	**Median**	**Mean**	**3rd Qu.**	**Max.**	**sd**	**p value**	
Group I	99	99	100	99,6667	100	100	0,488	0,1794	0,3389
Group II	90	99	99	98,7333	100	100	2,5204		
Group III	99	99	99	99,4667	100	100	0,5164	0,2849	0,6055
Group IV	99	99	100	99,6667	100	100	0,488		
SaO_2% 3	**Min.**	**1st Qu.**	**Median**	**Mean**	**3rd Qu.**	**Max.**	**sd**	**p value**	
Group I	94	95	95	95,3333	96	99	1,2344	0,0177	0,0601
Group II	92	96	97	96,8	98	99	1,8593		
Group III	92	94	95	94,5333	95	96	1,1872	0,0992	0,3374
Group IV	94	95	95	95,1333	95,5	96	0,6399		

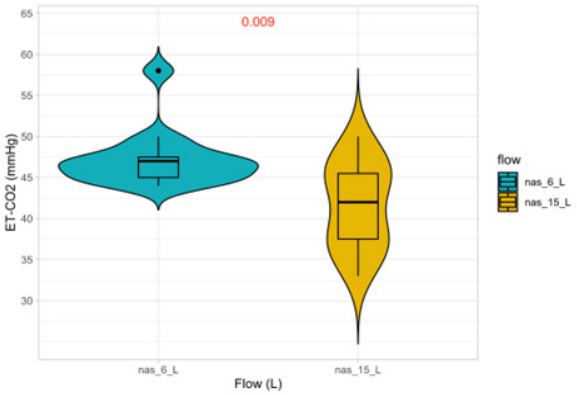


Figure 1. *Violin plot with a boxplot on ET-CO2 levels in patients on 6L flow and 15L flow, after intubation in nasal airway groups (group I, group II)*

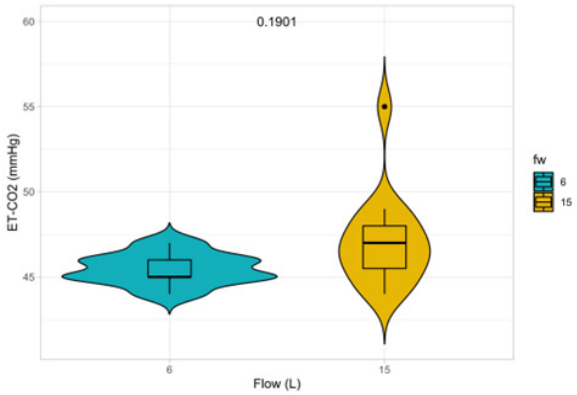


Figure 2. *Violin plot with a boxplot on ET-CO2 levels in patients on 6L flow and 15L flow, after intubation in facial mask groups (group III, group IV)*

at T2. There is 63.73mmHg decreased PaO2 in group I (with 6L/min) compared with group II (with 15L/min). According to the Cohen analysis, this is a significant effect (Cohen d=1.7124). Yet, the level of PaO2 at T2 between the facial mask groups (group III and group IV) did not show any difference.

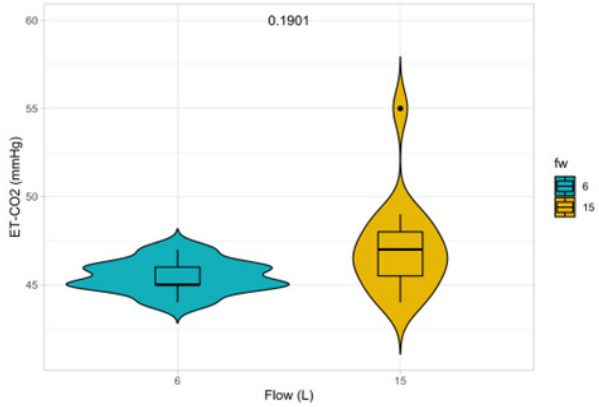


Figure 3. *Boxplot on the change in PaO2 levels at the end of apnea and in proximity to intubation in nasal catheter groups I and II.*

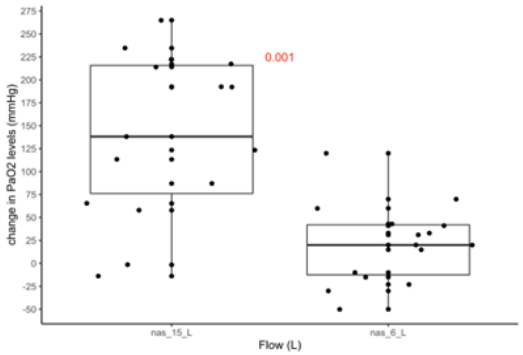


Figure 4. *Boxplot on the change in PaCO2 levels at the end of apnea and in proximity to intubation in nasal catheter groups I and II.*

The levels of PaCO2 are not significant at both investigated times (T1, T2) among all four groups. However, a Cohen analysis shows a significant effect of PaCO2 increase at T2, when compared between groups III and IV, those with a facial mask (Cohen d=1.1335).

DISCUSSION

Our results confirm that preoxygenation and apneic oxygenation with the maximum available flow of O2 from anesthesia machines (15L/min) in centers with limited resources can prolong the period of adequate oxygenation.

A common complication of endotracheal intubation is hypoxemia [11] and is more closely associated with cardiac arrest. [12] Preoxygenation is not always sufficient to ensure adequate oxygenation during intubation. [11, 13] An additional oxygen supply during the apnea period is advocated as an economical and safe intervention for improved oxygenation. [14–16]

Results from our study show that changes in PaO2 are significant in the nasal cannula groups I and II (15L flow). This leads to more time for safe airway manipulation, although PaO2 levels are at referent margins in the groups at 6L/min flow as well. Apneic oxygenation is used in the operation theaters. Despite apneic oxygenation before anesthesia induction, should difficult intubation be anticipated, this method is used for critically ill patients who require emergency operative treatment. [13, 17–19] HFNC is

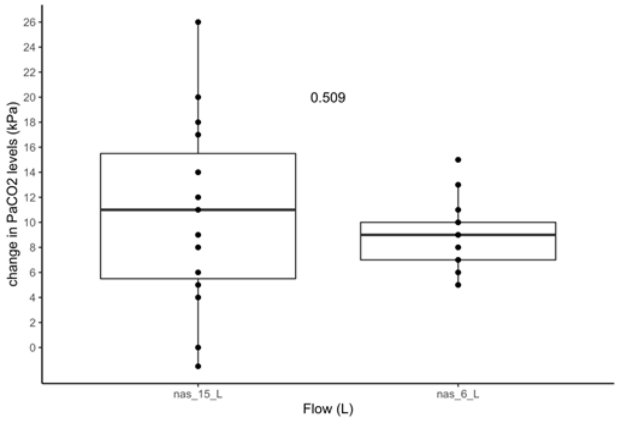


Figure 5. *Boxplot on the change in PaO2 levels at the end of apnea and in proximity to intubation in facial mask groups III and IV.*

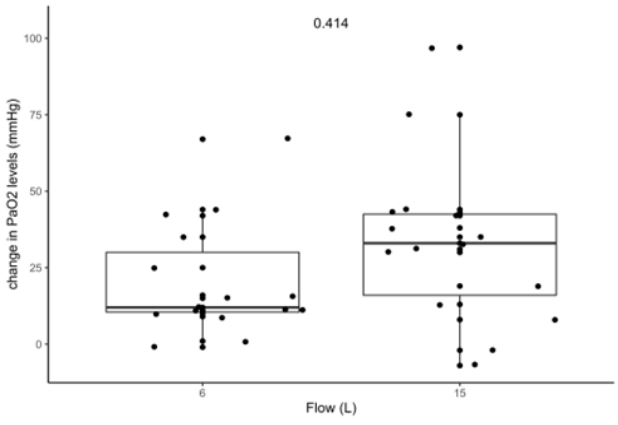


Figure 6. *Boxplot on the change in PaCO2 levels at the end of apnoea and in proximity to intubation in facial mask groups III and IV.*

Table 3. *Changes in arterial partial pressure of oxygen (PaO2) changes in T1 and T2 time points.*

PaO_2_1	Min.	1st Qu.	Median	Mean	3rd Qu.	Max.	sd	p value	q value
Group I	75	100,25	110	113,567	119	180	20,404	0,6382	0,9207
Group II	98	101,21	110,27	111,516	114,92	145,86	12,128		
Group III	98	99	110	111	119	145	13,538	0,4993	0,821
Group IV	98	101,5	109	108,2	111,5	124	8,1434		
PaO_2_2	**Min.**	**1st Qu.**	**Median**	**Mean**	**3rd Qu.**	**Max.**	**sd**	**p value**	**q value**
Group I	87	97	130	137,8	159	250	48,281	0,0004	0,0023
Group II	99	181,5	260	255,333	337	380	96,544		
Group III	108	110	130	131,533	145	187	24,776	0,3357	0,634
Group IV	100	119,5	145	141,467	154	201	30,435		
$dPaO_2$_(t2-t1)	**Min.**	**1st Qu.**	**Median**	**Mean**	**3rd Qu.**	**Max.**	**sd**	**p value**	
Group I	-50	-12,5	20	21,6667	42	120	43,685	0,0001	0,0011
Group II	-13,86	76,135	138,19	140,50	215,69	264,97	87,884		
Group III	-1	10,5	12	20,5333	30	67	18,681	0,1462	0,4143
Group IV	-7	16	33	33,27	42,5	97	27,057		

Table 4. *Changes in arterial partial pressure of carbon dioxide (PaCO2) changes in T1 and T2 time points.*

$PaCO_2$_1	Min.	1st Qu.	Median	Mean	3rd Qu.	Max.	sd	p value	q value
Group I	35	37	37	37,67	38	42	1,6762	0,709	0,861
Group II	29	36	39	37,2333	40,25	41	4,1008		
Group III	33	34,5	38	37,00	39	40	2,5355	0,543	0,821
Group IV	32	35	37	36,4667	38	40	2,1996		
$PaCO_2$_2	**Min.**	**1st Qu.**	**Median**	**Mean**	**3rd Qu.**	**Max.**	**sd**	**p value**	
Group I	42	44,5	45	46,40	48	55	3,1578	0,443	0,628
Group II	37	43,5	47	48,07	51,5	67	7,6108		
Group III	39	42	46	44,67	47,5	49	3,6384	0,022	0,126
Group IV	45	46	47	47,47	48,5	55	2,5598		
$dPaCO_2$_(t2-t1)	**Min.**	**1st Qu.**	**Median**	**Mean**	**3rd Qu.**	**Max.**	**sd**	**p value**	
Group I	5	7	9	8,73	10	15	2,8149	0,329	0,509
Group II	-1,5	5,5	11	10,83	15,5	26	7,6056		
Group III	4	5,5	7	7,67	8,5	15	2,9439	0,004	0,034
Group IV	7	8,5	10	11,00	13	16	2,8785		

also commonly used as a therapeutic treatment for ICU patients with respiratory failure. [5–9] Several studies have shown that HFNC or facial mask delivery of oxygen to paralyzed and anesthetized patients maintains oxygenation and achieves acceptable carbon dioxide concentrations. [2] This result fits with our previous investigations, [10] in that there are benefits in using all available O2 from the anesthesia machines. In addition, the effects of change in PaO2 and ETCO2 between the compared groups are high, which would likely provide more time for airway manipulation. Other randomized trials also report the use of apnea oxygenation in operating theaters. [17–19] A study by Taha et al. demonstrates that apnea oxygenation with 5L/min via a nasopharyngeal catheter, following pre-oxygenation with four deep breaths, in 20 to 52 year old patients, can prolong oxygenation for 2.65 minutes. [19] Another study from Baraka et al. provides similar results. [18] Nasopharyngeal catheter oxygenation followed by pre-oxygenation significantly prolonged the time of adequate oxygenation.

Ramchadan investigated supplemental apneic oxygen apply in difficult laryngoscopy of 30 obese patients. The study showed a prolonged saturation of > 95 % (5.29 ± 1.02 vs. 3.49

± 1.33 min, mean ± SD) (17). Our results also confirmed that in patients with a preoxygenation and apneic oxygenation of 15L/min O2 flow, the desaturation time was doubled (p=0.000). However, the aforementioned randomized studies in operation theaters, in contrast to ours, did not evaluate arterial blood gas analyses. In our evaluation, PaO2 changes are significant. Patients from group I with 6L/min have a lesser PaO2 when compared to group II with a 15L/min flow nasal cannula. This probably allowed us more time for the manipulation of the airway. In contrast to prior studies, Semlers' et al. study from a critical care group showed no difference between apneic oxygenation and usual care. A possible explanation for this is the necessity of intubation due to respiratory failure in these patients. The author suggests further investigation in a healthy subgroup population. [20] Our study, by contrast, consisted of patients who were healthy individuals without any positive history of respiratory disease. Another possible explanation could be the dose of apneic oxygenation delivered. We used the maximum available flow from the anesthesia machines, this was also recommended by experts. [14] In prior studies from operation room, [17–19] lower oxygen flows were used. An independent observer, unaware of the study hypothesis, collected the data endpoints, thus reducing potential observer bias. One study published last year did not demonstrate the benefits of using HFNC for preoxygenation of healthy volunteers before the induction of anesthesia, due to 90% increased ETCO2 in 46 % of the participants. [21] Our results show that group II had a 6.4 mmHg-decreased ETCO2. A false discover test did not confirm the p value of ETCO2 between groups III and IV.

There are several limitations to this study that could be addressed in future research. First, this is a single center study, thus limiting generalizability. Second, we did not use a limited group of doctors.

CONCLUSION(S)

The results of this study demonstrate that preoxygenation and apneic oxygenation with 15L/min are useful. We therefore suggest the use of maximum available oxygen flow from anesthesia machines for patients who undergo elective surgery in clinical settings where resources are limited. This method prolongs the time of adequate oxygenation and allows more time for safe airway management.

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Резиме

ОКСИГЕНАЦИЈА СО СРЕДЕН ПРОТОК ПРЕКУ ЛИЦЕВА МАСКА ИЛИ НАЗАЛНА КАНИЛА ВО ЦЕНТАР СО ЛИМИТИРАНИ РЕСУРСИ

Александра Гавриловска-Брзанов[1], Мирјана Шошолчева[2], Андријан Карталов[1], Марија Јовановски Срцева[1], Никола Брзанов[1], Билјана Кузмановска[1]

[1] Универзитетска клиника за трауматологија,ортопедски болести, анестезија, реанимација и интензивна нега, и ургентен хируршки центар, Медицински факултет, Универзитет „Св. Кирил и Методиј“ во Скопје, РС Македонија

[2] Универзитетска клиника за хируршки болести „Св. Наум Охридски“, Медицински факултет, Универзитет „Св. Кирил и Методиј во Скопје, РС Македонија

Вовед: Во центри со лимитирани ресурси, назалните канили со висок проток не се достапни. Нашата цел беше да процениме дали преоксигенацијата со 15 L кислороден проток достапен од машините за анестезија може да го пролонгира безбедниот период за вовед во анестезија пред интубација и дали ќе ни овозможи повеќе време за обезбедување на дишниот пат. Затоа, ја споредивме стандардната преоксигенација со 6 L кислород со 15 L преку назална канила и лицева маска.

Материјал и методи: Пациентите беа поделени во 4 групи. Пациентите во групапа 1 беа преоксигенирани со назална канила на 6 L кислород, во групата 2 со назална канила на 15 L кислород, во групата 3 со 6 L преку лицева маска и во групата 4 со 15 L преку лицева маска. Примарна цел беше времето на десатурација и интубација. Дополнителни цели беа PaO2, PaCO2, Sat% и ETCO2.

Резултати: Статистички сигнификантно и продолжено време на десатурација беше забележано кај групите преоксигенирани со 15 L. Пациентите од групата 2 има статистички сигнификантно повисоко PaO2 и пониско ETCO2 споредено со групата 1, додека кај пациентите од групите 3 и 4 имаше разлика само во PaCO2 и, иако оваа разлика е сигнификантна, двете групи има вредности во нормални граници.

Заклучок: Преоксигенацијата со максимален достапен кислород од машините за анестезија во центирте со лимитирани ресурси е корисна. Таа го пролонгира безбедното време за манипулација со дишен пат. Предлагаме употрба на максимален проток на кислород достапен од анестезиолошките машини во клиничката практика.

Клучни зборови: преоксигенација, кислороден проток, оксигенација, лицева маска, назална канила, ендотрахеална интубација