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ORIGINAL ARTICLE / ÖZGÜN ARAŞTIRMA MAKALESİ

Evaluation of Brain Oxygenation by Near Infrared Spectroscopy in Healthcare Professionals Using Surgical and FFP2/N95 Masks

Cerrahi ve FFP2/N95Maske Kullanan Acil Servis Çalışanlarında Near Infrared Spectroscopy ile Beyin Oksijenizasyonunun Değerlendirilmesi

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ABSTRACT

Aim: The present study aimed to detect changes in brain oxygenation associated with the use of surgical and FFP2/N95 masks using the near infrared spectroscopy (NIRS) method.

Material and Methods: Volunteers wearing surgical masks were asked to sit upright for 30 minutes. Cerebral oxygen saturation values were measured at the 1st, 5th, and 30th minutes (group 1). The mask wearers were requested to return at the same time on the day following this procedure. In group 2, serial cerebral oxygen saturation values (SpO2) were obtained at the same time intervals as in group 1, but while the subjects were wearing FFP2/N95 masks.

Results: A statistically significant difference was found between the groups in the comparison of the values measured using NIRS at the 1st, 5th, and 30th minutes in group 1. According to the post-hoc analysis, this difference was due to discrepancies in NIRS measurements at the 1st minute and 30th minute and at the 5th minute and 30th minute. No statistically significant difference was found between the groups in the comparison of the values measured using NIRS at the 1st, 5th, and 30th minutes in group 2.

Conclusion: Neither surgical nor FFP2/N95 masks caused a clinically significant negative difference in brain oxygenation.

Keywords: Mask, oxygenation, near infrared spectroscopy, oxygen saturation, volunteers

ÖZ

Amaç: Bu çalışma, Near infrared spektroskopi (NIRS) yöntemini kullanarak cerrahi ve FFP2/N95 maskelerinin kullanımıyla ilişkili beyin oksijenasyonundaki değişiklikleri tespit etmeyi amaçladı.

Gereç ve Yöntemler: Cerrahi maske takan gönüllülerden 30 dakika dik oturmaları istendi. 1., 5. ve 30. dakikalarda (grup 1) serebral oksijen satürasyonu değerleri ölçüldü. Maske takanların bu işlemin ertesi günü aynı saatte gelmeleri istendi. Grup 2'de seri serebral oksijen satürasyonu değerleri (SpO2) grup 1 ile aynı zaman aralıklarında ancak denekler FFP2/N95 maskesi takarken elde edildi.

Bulgular: Grup 1'de 1., 5. ve 30. dakikalarda NIRS ile ölçülen değerlerin karşılaştırılmasında gruplar arasında istatistiksel olarak anlamlı fark bulundu. Post-hoc analize göre bu fark, 1. dakika ve 30. dakika ve 5. dakika ve 30. dakikada. Grup 2'de 1., 5. ve 30. dakikalarda NIRS ile ölçülen değerlerin karşılaştırılmasında gruplar arasında istatistiksel olarak anlamlı fark bulunmadı.

Sonuç: Ne cerrahi ne de FFP2/N95 maskeleri, beyin oksijenasyonunda klinik olarak anlamlı bir negatif farklılığa neden olmadı.

Anahtar Kelimeler: Maske, oksijenasyon, near infrared spectroscopy, oksijen saturasyonu, gönüllüler

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Introduction

In the face of a life-threatening pandemic, the mask has become the leading personal protective equipment to stop the spread of SARS-CoV-2 and to ensure the safety of patients and healthcare workers (1). Patients and healthcare professionals perform their daily activities with a mask for prolonged time periods (2). Medical masks have a negative impact on cardiopulmonary capacity, which significantly interferes with strenuous and physical activities. In addition, medical masks significantly impair the quality of life of the wearer (3). Masks are generally considered uncomfortable for regular use and may result discomfort due to not being worn properly (4, 5). However, when FFP2/N95 masks and surgical masks are compared, there is no significant difference in terms of the risk of not being worn at the workplace (6). In addition, adequate personal protective equipment is considered as the key to reducing the risk of adverse psychological consequences (7).

Near-infrared spectroscopy (NIRS) is a non-invasive technology that continuously monitors tissue oxygenation, especially that of the brain (8). The mechanism of NIRS (NIR: near-infrared; wavelength: 700-1100 nm) includes measurement of the amount of near-infrared light absorption by chromophore molecules (9). Cerebral NIRS has been reported to demonstrate silent periods of cerebral ischemia, thus playing an important role in maintaining brain function (10). Although NIRS has primarily been used for measurement of cerebral oxygenation during carotid endarterectomy and perioperative surgery, it can be used in case of shock and acute brain injury, and especially cardiopulmonary resuscitation (CPR) in emergency department. There is evidence to suggest that it can be helpful in detecting the return of spontaneous circulation during CPR (11).

Pulse oximetry measurement has limitations in hypoxic state. It is difficult to use in the presence of anemia, light interference, skin pigmentation, venous pulsations and low perfusion. Unlike peripheral oxygen saturation (SpO2), pulsatile flow measurement is also not required during NIRS measurement. It has also been shown that NIRS measurement provides earlier alert than pulse oximetry in hypoxic state (12, 13).

Although we struggle to control this pandemic and maintain an adequate supply of personal protective equipment, it is important to evaluate the effect of personal protective equipment on humans. Our study aimed to detect the changes in brain oxygenation associated with the use of surgical and FFP2/N95 masks using the NIRS method. To our knowledge, our study is the first of its kind to evaluate the effect of surgical and FFP2/N95 masks on brain oxygenation.

Material and Methods

This study was conducted in the emergency department of a training and research hospital between November 2020 and February 2021. Ethics committee approval was obtained from the hospital's ethics committee for the study, (ethics committee approval number: 18/1/2021-221426) and informed consent was obtained from all volunteers before the procedures.

Participants

Forty healthy emergency medicine staff between the ages of 18 and 42 years were included in the study. Volunteers who had chronic diseases or were pregnant were excluded from the study.

Study Protocol

We aimed to eliminate the demographic differences between the two groups by designing the study with the same volunteers. Hence, the same volunteers were included in the surgical mask group (group 1) and the FFP2/N95 mask group (group 2). All volunteers were asked to sleep at least 8 hours the night before the study and to arrive at the same time in the morning on the study day. Demographic data (age, gender, height, and weight) of the volunteers were recorded. On the first day, the volunteers wore a surgical mask and were asked to sit upright on a hospital stretcher for 30 min. Data on cerebral oxygen saturation, arterial tension, fingertip oxygen saturation, and heart rate measurements of volunteers wearing surgical masks were recorded at the 1st, 5th, and 30th min. The volunteers were asked to arrive at the same time on the following day to minimize any possible daily biological rhythm changes. At this second visit, the volunteers put on a FFP2/N95 mask. Cerebral oxygen saturation, arterial tension, fingertip oxygen saturation, and heart rate measurements were obtained at the same time intervals as that during the procedure in group 1. The typical and widely used disposable FFP2/N95 protective face masks (Era®, Korfez Is Güvenlik Malzemeleri San. Ve Tic Ltd Sti., Istanbul, Turkey) and surgical masks (Evony®, Hayat Kimya San. A.S. Istanbul, Turkey) with ear loops, were used in this study.

Cerebral Oxygen Saturation Measurement

A low frequency emitting source, such as a light emitting diode or a continuous intensity laser, and a detection device that can detect these low frequencies are used in NIRS measurements. During these measurements, data on fractional tissue oxygen extraction, which measures the balance between oxygen distribution and consumption in the tissue, is obtained. An INVOS 5100C cerebral/somatic oximeter (Covidien) with a near infrared cerebral oximetry system was used for cerebral oxygen saturation measurements using this measurement method. The measurements were made with electrodes attached to the forehead and recorded continuously.

Statistical Analysis

Data obtained were analyzed with SPSS version 26.0. (IBM Corp. Released 2019. IBM SPSS Statistics for Windows, Armonk, NY: IBM Corp). The normality of the data distribution was tested by Shapiro–Wilk test, histogram, and Q–Q Plot. Normally distributed continuous data were expressed as mean (± standard deviation), non-normally distributed continuous data as median (25%–75% interquartile range), and categorical data as frequency (%).

The dependent multiple group comparisons were made using repeated measures analysis of variance (ANOVA) for variables that met ANOVA conditions, and Friedman test for variables that did not meet ANOVA conditions. Bonferroni and Wilcoxon tests were used for post-hoc analysis, respectively, followed by application of Bonferroni correction.

A difference greater than 5% between the groups was considered clinically significant for NIRS measurements (14).

Results

A total of 40 volunteers were included in the study. Of these, 16 (40%) were women. The mean age of the volunteers was 28 years (± 5), their mean height was 172 cm (± 8), and their median weight was 69 kg (55–80). The basic descriptive characteristics of the volunteers are summarized in Table 1.

	Mean (SD) / n (%)	Median [%25-75 IQR]
Age	28.2 (5)	28.0 [25.0-30.0]
Sex (Female)	16 (40)	
Length (cm)	171.7(8)	
Weight (kg)		69.0 [55.25-79.75]
Body-Mass Index	23.4(3.9)	
Surgical mask group, vital values before intervention		
Systolic TA (mmHg)	118(11)	
Diastolic TA (mmHg)		75 [69-81]
Heart rate (beats per minute)	83(10)	
SpO_2		98 [97-99]
FFP2/N95 mask group, vital values before intervention		
Systolic TA (mmHg)	118(12)	
Diastolic TA (mmHg)		70 [65-76]
Heart rate (beats per minute)	81(11)	
SpO_2		98 [97-99]

Descriptive statistics were expressed as mean standard deviation and median (IQR) for metric variables. Categorical variables were presented as number (%). IQR: Interquartile range, TA: arterial tension

Table 1. Basic descriptive characteristics of volunteers

The mean NIRS measurements of group 1 at the 1st, 5th, and 30th min were 70 (± 9), 70 (± 8), and 68 (± 8), respectively, and those of group 2 were 70 (± 8), 69 (± 7), and 68 (± 8), respectively.

When the NIRS measurement values of group 1 at 1, 5, and 30 min were compared, a statistically significant difference was found (p = 0.001, repeated measures ANOVA). In the post-hoc analysis, it was observed that the difference was due to the difference between NIRS measurements at 1 min and 30 min and at 5 min and 30 min (p = 0.016 and p = 0.001, respectively, with Bonferroni correction applied).

When the 1st, 5th, and 30th min NIRS measurement values of group 2 were compared, no statistically significant difference was observed (p = 0.136, Repeated Measures ANOVA).

The primary outcome measures were summarized in Table 2.

	NIRS 1st minute Mean (SD)	NIRS 5th minute Mean (SD)	NIRS 30th minute Mean±SD	P value
Surgical Mask	70(9)	70(8)	68(8)	**.001***
FFP2/N95 Mask	70(8)	69(7)	68(8)	.136

Descriptive statistics were expressed as mean±standard deviation. P-values written in bold are statistically significant (P<.05).

* In the post-hoc analysis, it was seen that the difference was due to the NIRS measurements at 1st minute to 30th minute and from 5th to 30th minutes. (P=.016, P=.001 respectively, Bonferroni correction was applied).

Table 2. NIRS measurement values of surgical mask and FFP2 / N95 mask groups at 1st, 5th and 30th minutes

In group 1, the median oxygen saturation (SpO2) values for measurements made at 1, 5, and 30 min were 98 (97–99), 98 (97–98), and 98 (97–98), respectively, and those of group 2 were 98 (97-99), 98 (97-99), and 98 (97-99), respectively. No statistically significant difference was found among the within group SpO2 measurements of group 1 and 2 at the 1st, 5th, and 30th min (p = 0.279, p = 0.166, respectively) (Table 3).

	SpO_2 1st minute Median [%25-75 IQR]	SpO_2 5th minute Median [%25-75 IQR]	SpO_2 30th minute Median [%25-75 IQR]	P value*
Surgical Mask	98 [97-99]	98 [97-98]	98 [97-98]	.279
FFP2/N95 Mask	98 [97-99]	98 [97-99]	98 [97-99]	.166

Descriptive statistics were expressed as median [IQR]. IQR: Interquartile range

* Friedman test was used.

Table 3. SpO_2 measurement values of surgical mask and FFP2 / N95 mask groups at 1st, 5th and 30th minutes

The difference between before-the-intervention sPO2 and 30th minute sPO2 measurements was named ΔsPO2. The median ΔsPO2 of the surgical mask group was 0 (-1 to 1), and the median ΔsPO2 of the FFP2 mask group was 0 (0 to 1).

The mean heart rates of group 1 at the 1st, 5th, and 30th min were 83 bpm (79–88), 82 bpm (76–92), and 79 bpm (72–88), respectively, and those in group 2 were 80 bpm (73–88), 80 bpm (73–90), and 78 bpm (71–89), respectively. When the heart rates of group 1 at 1, 5, and 30 minutes were compared, a statistically significant difference was found (p = 0.048, Friedman test). However, in the post-hoc analysis performed for the heart rate differences between the 1st and 5th min, 1st and 30th min, and 5th and 30th min, no statistically significant difference was found after applying the Bonferroni correction (p = 1, p= 0.174, and p = 0.072, respectively, Wilcoxon test, with Bonferroni correction applied).

When the measured heart rate values of group 2 at the 1st, 5th and 30th minutes were compared, a statistically significant difference was found (p = 0.031, Friedman). However, in the post-hoc analysis performed for the heart rate differences between the 1st and 5th min, the 1st and 30th min, and 5th and 30th min, no statistically significant difference was found between the groups after applying Bonferroni correction (p = 1, p = 0.264, p = 0.090, respectively, Wilcoxon test, with Bonferroni correction applied) (Table 4).

	Heart rate 1st minute Median (%25-75 IQR)	Heart rate 5th minute Median (%25-75 IQR)	Heart rate 30th minute Median (%25-75 IQR)	P value
Surgical Mask	83 [79-88]	82 [76-92]	79 [72-88]	**.048***
FFP2/N95 Mask	80 [73-88]	80 [73-90]	78 [71-89]	**.031***

IQR: Interquartile range

* Although a significant difference was detected in the Omnibus test, no statistically significant difference was found in post hoc analyzes (Wilcoxon test was used.)

Table 4. Heart rate measurement values of surgical mask and FFP2 / N95 mask groups at 1st, 5th and 30th minutes

Discussion

NIRS is used for early and noninvasive detection of cerebral hypoperfusion. Particularly in patients with carotid artery stenosis, close monitoring is provided, and technical and medical interventions can be performed by using NIRS (15). Unlike other oximetric measurements, the NIRS oximeter does not require pulsatile or non-pulsatile blood flow (16). Measurements obtained during NIRS are expressed as %, and brain regional cerebral oxygen saturation (rSo2) median values in adult patients were found to be 66% (IQR 61-71) (17). The NIRS value falls and brain perfusion decreases with age, especially in individuals with cardiovascular diseases (18). In our study, the mean NIRS values of group 1 at the 1st, 5th, and 30th min were 70 (± 9), 70 (± 8), and 68 (± 8), respectively, and that of group 2 were 70 (± 8), 69 (± 7), and 68 (± 8), respectively. Although there was no statistically significant difference in the 1st, 5th, and 30th minute NIRS values of group 2, a statistically significant difference was found in these values in group 1. Even though the difference was statistically significant, it was not clinically significant (14). An experimental study conducted in healthy individuals, which was similar to our study, showed no decrease in brain oxygenation despite decreased oxygen supply and carbon dioxide elimination (19). Accordingly, we believe that neither the surgical mask nor the FFP2/N95 mask impairs brain perfusion within a short period of time.

No statistically significant difference was found in the SpO2 measurements within groups 1 as well as 2. In a study, although the use of masks in healthy young male volunteers caused a minimal decrease in SpO2 during an aerobic exercise for 75 min, the decrease was not found to be statistically significant (20). In another study conducted on 14 volunteers, no difference in SpO2 and an increased heart rate was observed among the no mask, surgical mask, and FFP2/N95 mask groups after exercise at a mean age of 59 years. The use of a mask was recommended even during exercise (21). In a study without a control group, the saturation levels of 25 oral surgeons were measured while they wore masks and performed surgeries, and the measurements were taken throughout the surgery, which lasted 20 min. The effects of underlying medical conditions, age, and gender were not evaluated, and the saturation levels were found to be 97.5% before the surgery and 94% after the surgery (22). In a study conducted on patients with chronic obstructive pulmonary disease, a significant decrease in SpO2 was observed even while walking with the FFP2/N95 mask (23).

The mean heart rates of the group 1 at the 1st, 5th, and 30th min were 83 bpm (79–88), 82 bpm (76–92), and 79 bpm (72–88), respectively, and that of group 2 were 80 bpm (73–88), 80 bpm (73–90), and 78 bpm (71–89), respectively. No statistically significant difference was found in either group. In similar studies, it has been determined that both types of masks had a minimal effect on heart rate, which was not statistically significant in healthy volunteers (20, 21). In particular, breathing resistance, temperature, tension, and general discomfort are the factors that have the greatest impact on subjective perception. These factors can increase the heart rate relatively (3). A study comparing FFP2/N95 and surgical masks in 5 male and 5 female volunteers found that a small physiological effect became detectable during moderate to high intensity exercise in FFP2/N95 mask wearers (24, 25). Although there are studies reporting that there may be increases in heart rate, especially in those with comorbidities, the findings suggest that the widespread use of masks may be reasonable even for those with underlying heart disease, lung disease, and other comorbidities (22, 23, 25).

Limitations

The most important limitation of the study was that it was performed in healthy and young volunteers. Therefore, it may be difficult to generalize our results to elderly patients with comorbidities, particularly those with respiratory and cardiovascular diseases. In this research, we evaluated wearing mask for the first 30 minutes. The effect of longer duration of wearing mask and wearing mask with movement was not investigated in this article.

Conclusion

Neither surgical masks nor FFP2/N95 masks caused a clinically significant negative difference in brain oxygenation according to our measurements. There was no clinically significant difference between the surgical mask and the FFP2/N95 mask in terms of SpO2 reduction and heart rate increase. Further studies are needed on the long-term use of these masks and in populations at risk for impaired cerebral perfusion (e.g., underlying lung disease, cardiac disease, or cerebrovascular disease).

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