RESEARCH ARTICLE

The effect of mask usage of the health personnel on blood gas analysis and cognitive strengthening during COVID-19 pandemic

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Abstract

Objective: To investigate the effect of lengthy mask use on blood gas values and cognitive functions.

Method: The cross-sectional study was conducted in February and March 2022 at Mersin City Training and Research Hospital, Mersin, Turkey, and comprised healthcare professionals of either gender aged 20-60 years working in the 3rd level intensive care unit. Each volunteer was subjected to venous blood gas analysis at the beginning and end of the 8-hour morning shift. Coronavirus disease-2019 status was noted, and further data related to cognitive functions was collected using a 7-item questionnaire. Data was analysed using SPSS 20.

Results: Of the 63 subjects, 43(68.3%) were women and 20(31.7%) were men. The overall mean age was 33.53±6.76 years. There were 42(66.7%) subjects using N95 mask; 27(64.3%) women and 15(35.7%) men with mean age 32.38±6.54 years. There were 21(33.3%) subjects wearing surgical masks; 16(76.2%) women and 5(23.8%) men with mean age 35.95±0.76 years. Intergroup comparisons were non-significant for all the markers (p>0.05). Within the N95 mask group, potential of hydrogen and lactate values were significantly different (p<0.05), while in the surgical mask group, potential of hydrogen and partial pressure of oxygen were significantly different (p<0.05). There were 28(66.7%) subjects in the N95 group who had been affected by coronavirus disease-2019 compared to 16(76.2%) in the surgical mask group (p>0.05). Subjects in the N95 mask group had significant impaired cognitive functions compared to the surgical mask group (p<0.05).

Conclusion: Impairment in cognitive functions in intensive care unit workers using masks could be explained by the development of intermittent long-term moderate hypoxia.

Key Words: Masks, Coronavirus, Carbon dioxide, Hypoxia.

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Introduction

The coronavirus disease-2019 (COVID-19) pandemic caused >5 million deaths around the world, millions of others had to undergo treatment in intensive care units (ICUs) with respiratory support [1]. In such a scenario, the necessity of using personal protective equipment (PPE), especially in ICU workers, and the prolongation of the pandemic period inevitably brought along a series of health problems for healthcare workers (HCWs) [2]. Working conditions, such as long and strict use of masks, especially N-95 and surgical masks, of ICU workers, uncertainties at the beginning of the pandemic, and equipment deficiencies were important stressors [1,2]. The possibility of developing intermittent, long-term hypoxia and hypercarbia due to the use of masks among HCWs during the pandemic, leading to negative physiological and psychological effects on ICU workers have been inadequately studied by a few researchers without achieving a definite result [2-4]. The current study was planned to investigate the effect of mask use on blood gas values and cognitive functions among ICU HCWs.

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Subjects and Methods

The cross-sectional study was conducted between February and March 2022 at Mersin Şehir Training and Research Hospital, Mersin, Turkey. After approval of the ethics review committee of Mersin University, the sample size was obtained from a previous study which was then raised by 20%.[5] The sample was randomised using computer-generated random numbers, and written informed consent from all the subjects was obtained. Those included were HCWs of either gender aged 20-60 years working in the 3rd level ICU, and who did not have a malignant, chronic systemic disease. Those with any chronic disease, women with pregnancy, and those not willing to participate were excluded.

Each volunteer was allowed a 90-minute break to go out of the working environment during the eight-hour morning shift. Venous blood samples were taken from the subjects at the beginning of the shift (Sample 1) and 8 hours later at the end of the shift (Sample 2).

Blood gas analysis, including potential of hydrogen (pH), partial oxygen pressure (pO2), partial carbon dioxide pressure (pCO2), oxygen saturation (satO2) and lactate levels, was performed using a blood gas analyser (Siemens, Siemens RP1265-2016 Germany) within the ICU without any time delay. COVID-19 status was noted, and further data related to cognitive functions was collected using a 7-item questionnaire.

Data was analysed using SPSS 20. Data distribution was assessed using Kolmogorov-Smirnov test. Categorical data was presented as frequencies and percentages, while numerical data was presented as mean ± standard deviation. Chi-square test was used to compare categorical data. The comparison of blood gas analysis results in relation to the type of mask used was performed by Mann-Whitney U test. Intragroup comparisons were done using Wilcoxon test. P<0.05 was taken as statistically significant.

Results

Of the 63 subjects, 43(68.3%) were women and 20(31.7%) were men. The overall mean age was 33.53±6.76 years. There were 42(66.7%) subjects using N95 mask; 27(64.3%) women and 15(35.7%) men with mean age 32.38±6.54 years. There were 21(33.3%) subjects wearing surgical masks; 16(76.2%) women and 5(23.8%) men with mean age 35.95±0.76 years. Intergroup comparisons were non-significant for all the markers (p>0.05). Within the N95 mask group, pH and lactate values were significantly different (p<0.05), while in the surgical mask group, pH and pO2 values were significantly different (p<0.05) (Table 1).

There were 28(66.7%) subjects in the N95 group who had been affected by COVID-19 compared to 16(76.2%) in the surgical mask group (p>0.05). Subjects in the N95 mask group had significant impaired cognitive functions compared to the surgical mask group (p<0.05) (Table 2).

Table-1: Demographic characteristics and blood gas analysis

	Mask type		
	Surgical mask N (%)	**N95 N(%)**	***P*-Value**
Gender			
Female	16 (76.2)	27 (64.3)	0.339
Male	5 (23.8)	15 (35.7)	
	(Mean±SD)	**(Mean±SD)**	
Age (years)	35.95±0.76	32.38±6.54	
pH-1st measurement	7.35±0.026	7.35±0.028	0.481#
p02-1st measurement	33.12±11.31	34.26±12.53	0.683#
pC02-1st measurement	45.43±12.09	45.95±10.47	0.771#
sat02-1st measurement	39.85±18.83	40.84±20.29	0.971#
Lactate-1st measurement	0.69±0.38	0.84±0.40	0.258#
pH-2nd measurement	7.37±0.034	7.37±0.030	0.681#
p02-2nd measurement	30.04±11.18	32.99±10.12	0.255#
pC02-2nd measurement	43.14±13.03	46.04±8.39	0.683#
sat02-2nd measurement	38.82±18.42	44.84±20.32	0.238#
Lactate-2nd measurement	0.62±0.27	0.72±0.36	0.389#

SD: Standard deviation, pH: Potential of hydrogen, $p0_2$: partial oxygen pressure, pCO_2: partial carbon dioxide pressure, SatO2: Oxygen saturation. *p<0.05

#Mann-Whitney U test.

αWilcoxon test

Intragroup comparisons between 1st and 2nd measurements in the surgical mask group:

pH: p=0.002α, $p0_2$: p=0.004α*, pCO_2: p=0.394α, sat02: p=0.566α, Lactate: p=0.267α.

Intragroup comparisons between 1st and 2nd measurements in the N95 mask group: pH: p=0.002α*, $p0_2$: p=0.160α, pCO_2: p=0.764α, sat02: p=0.468α, Lactate: p=0.018.*

Table-2: Cognitive functions

	Mask type		
	Surgical mask N (%)	**N95 N(%)**	***P*-Value**
I'm nervous (Yes)	7 (33.3)	14 (33.3)	>0.05
I am forgetfull (Yes)	7 (33.3)	23 (54.8)	0.108
I am having trouble on focussing (Yes)	7 (33.3)	14 (33.3)	>0.05
I have distraction problem (Yes)	9 (42.9)	13 (31)	0.350
I am getting tired quickly (Yes)	14 (66.7)	28 (66.7)	>0.05
I am not as patient as before (Yes)	12 (57.1)	16 (38.1)	0.151
I use more painkillers than before (Yes)	9 (42.9)	16 (38.1)	0.716
Impairment in Cognitive Functions (Present)	65	124	<0.05*
I had COVID-19 (Yes)	16 (76.2)	28 (66.7)	0.437

COVID-19: Coronavirus disease-2019. *p<0.05

Chi-square test

Discussion

The current study found that pO_2 value decreased after 8 hours of surgical masks usage in HCWs, the pH value increased in both the groups, and the lactate value decreased in the N95 mask group. Cognitive functions were found to be more impaired in the N95 mask group compared to the surgical mask group.

During the COVID-19 pandemic, severe psychological changes, including anxiety and depression, were frequently observed, having significant negative impact in cognitive functions, such as memory weakness, focussing on problems and irritability in ICU HCWs [2-4]. As in any environment where protective masks are used, chronic hypoxia at different levels has negative effects on the central nervous system (CNS), especially on cognitive functions, but some studies have reported certain positive effects as well[4,6].

In the current study, pO_2 2nd measurement in both single-use three-ply surgical mask and N95 mask groups was found to be low compared to the 1st measurement at the end of the 8-hour shift. Studies evaluating blood gas analysis have revealed a strong correlation between venous and arterial blood gas samples for pCO_2, pH values, and a weak correlation for pO_2 and $satO_2$ values, asserting that venous blood gas can provide information about respiratory functions [5,7]. In addition, one possible explanation for the higher pO_2 measurement of N95 compared to surgical mask could be the difference between the physical structure of the two masks.

Results related to pCO_2 level suggested that the surgical masks may have allowed CO_2 leakage, and those using the N95 masks may have re-breathed some of their own exhaled air. Studies have shown that hypercarbia under mask initially developed during the adaptation process to the mask which rapidly returns to normal levels. In the present study, this mechanism could be explained by the involvement of the compensatory respiratory dynamics [8,9]. The pH values in both groups were higher after 8 hours, but the difference was not significant. Likewise, the decline in lactate level in the N95 group was also not significant.

Robberge et al. reported that the type of mask did not improve pCO_2 level among HCWs [9].

Li et al. reported that muscle mitochondria may reduce the ability to use oxygen, thus affecting exercise capacity[8].

Blood gas analysis has revealed negative effects of long-term use of protective masks on CNS, cardiovascular system (CVS) and respiratory system [3,8,9].

The present findings are in line with literature related to the negative effect on cognitive and physical functions owing to long-term intermittent low-level hypoxia [8,10-13]. It is known that the possibility of developing intermittent and long-term hypoxia and hypercarbia could not be underestimated [3,4,9].

In a remarkable study comprising 60 volunteers divided into surgical and N95 masks [14], brain oxygenation was evaluated using cerebral blood oxygenation level dependent magnetic resonance imaging (BOLD-MR) at the beginning and end of a 6-hour shift. Headache was the most common symptom in both groups. In addition, clinical symptoms such as nausea, vomiting, dizziness, blurred vision, drowsiness and fatigue, were observed more frequently in the N95 group, but also in the other group [14].

The pathophysiology of cerebral hypoxia is complex and multifactorial, and the severity and duration of hypoxia are important parameters. In this context, hypoxia is categorised as acute hypoxic hypoxia and chronic hypoxic hypoxia [15-17]. A broad definition can be made for the duration of acute hypoxia and chronic hypoxia from seconds, hours, days and years. Cerebral vascular vessels respond with a change in vessel diameter when the pO_2 level decreases <50mmHg and in hypercapnia. Carbon dioxide is a potent vasodilator, leading to dilatation of the pial vessels, and a decrease in vascular resistance, resulting in an increase in cerebral blood flow (CBF) through the common carotid artery (CCA). Vasodilation also occurs in the intracranial and extracranial arteries, as well as carotid and vertebral arteries. In chronic hypoxia, blood is directed to vital centres in the brain stem. While cellular oxygenation is maintained, other non-vital brain regions remain relatively hypoxic [18].

Cerebral oxygenation is affected in the frontal lobe and anterior cingulate gyri. These regions manage the compensation mechanism for cognitive functions. The clinical mechanism of confusion was also explained by the demonstration of insufficient blood redistribution and compensation using BOLD-MR in 7 subjects[14,15,18]. However, there is still no consensus on the definition of intermittent hypoxia [10,11]. It has been stated that the effect of intermittent hypoxia on many organ systems is related to a number of variables [8,10].

With respect to the neurophysiological basis of the effects of hypoxia on cognitive functions, it has been reported that it causes some disorders ranging from metabolic homeostasis to the deterioration of neural integrity by causing molecular damage, depending on the severity of hypoxia. Cognitive functions, such as attention, information storage, retrieval and processing speed, are supported by many large-scale neural networks. The primary and sensory cortex with some of parietal and frontal regions join this network anteriorly. It has been shown that these regions are affected in hypoxic and ischaemic memory disorders. It has been reported in various studies that there are regions of the brain that are sensitive to oxygen deficiency, especially those are closely related to cognitive functions [6,19,20]. The effects of hypoxia on CNS and CVS, and the cellular changes that have been shown to affect the mental state, may be sufficient to explain the response of ICU HCWs that was observed in the current study where many reported feeling tired ‘more quickly’.

Besides, it is not difficult to say that heavy work conditions may have an accumulated stress effect during the pandemic process. Mecit et al. showed an increase in burnout syndrome where anxiety and depression were observed during the pandemic [3]. The current findings related to a number of people reporting being angry and not as patient as they used to be, supported the existence of psychological fluctuations during the pandemic.

The current study has some limitations, including single-centre data related to HCWs having a single nationality. Besides, arterial blood gas analysis was not done. The limitations have affected the generalisability of the findings. More comprehensive studies are needed to validate the current findings.

Conclusion

Impairment in cognitive functions in ICU HCWs using masks could be explained by the development of intermittent long-term moderate hypoxia. Besides, ICU working conditions during the pandemic were important stress factors.

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Author's Contributions

HO: Conceptualization, investigation, methodology, writing, original draft preparation.

SD: Conceptualization, Analysis investigation, validation writing, supervision.

BA: Conceptualization, investigation, methodology, writing, supervision.

HEE: Formal Analysis investigation.