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THE EFFECT OF WEARING AN FFP3 MASK (3M™ AURA™) WITH AN EXHALATION VALVE ON GAS EXCHANGE IN MEDICAL STAFF

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Abstract
Objectives: The physiological impact of wearing personal protective equipment (PPE), in particular filtering-face-piece 3 (FFP3) masks, has increasingly been gaining importance since the outbreak of coronavirus disease 2019 (COVID-19). So far, gas exchange has been examined using transcutaneously measured partial pressure of carbon dioxide ($PaCO_2$), ergo-spirometry and impedance cardiography. **Material and Methods:** In this structured investigation, arterial blood gas analysis in a 30-year-old female resident was carried out during a 13-hour day shift on the COVID-19 Intensive Care Unit of the University Hospital of Innsbruck, Austria. An FFP3 mask (3M™ Aura™) with an exhalation valve was continuously worn, except for 1 break of 20 min. Arterial blood samples were obtained before putting on the PPE, and after 5 h, 9 h and 13 h of working in the contaminated area. **Results:** During the multi-hour wearing time, an increase in $PaCO_2$ (the baseline value: 29.3 mm Hg, the max. value: 38.9 mm Hg) and a continuous decrease in partial pressure of oxygen (PaO_2, the baseline value: 102 mm Hg, the min. value: 80.8 mm Hg) was detectable. **Conclusions:** All measured values were within the normal range, but a trend towards an insufficient gas exchange could be suspected. Int J Occup Med Environ Health. 2021;34(6)

Key words:
personal protective equipment, health personnel, gas exchange, respiratory protective devices, COVID-19, masks

INTRODUCTION

Ensuring the best possible protection of the healthcare professionals directly caring for coronavirus disease 2019 (COVID-19) patients is of utmost importance. According to recent guidelines, the recommended personal protective equipment (PPE) consists of a filtering-face-piece (FFP)/N95 mask, an isolation gown or coveralls, gloves, a face shield or goggles [1,2].

Working under these conditions confronts medical staff with challenges. Besides mental stress, wearing protective clothing over a long period of time, in combination with insufficient breaks, results in physical strains.

It is already known that the use of FFP2/N95 masks in particular may cause skin damage like rush, infections, and ulcers [3]. At present, the possible effect of wearing a face mask on the cardiopulmonary system is in the center of multiple clinical trials [4]. However, data on gas exchange detected by blood gas analyses in healthcare professionals has so far been scarce. To contribute to the current discussion, a self-experiment regarding the physiological impact of wearing an FFP3 mask was conducted on the COVID-19 Intensive Care Unit (ICU) at the University Hospital of Innsbruck, Austria.

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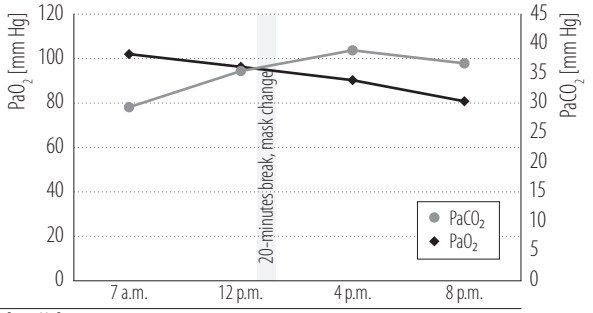

PaO_2 [mm Hg]	102	96.3	90.3	80.8
$PaCO_2$ [mm Hg]	29.3	35.4	38.9	36.7

Figure 1. Arterial blood gas analysis of a female resident (N = 1) during 13-hour day shift at COVID-19 Intensive Care Unit, the University Hospital of Innsbruck, Austria, April 2020

METHODS

In April 2020, arterial blood gas analysis in a 30-year-old female resident was carried out during a general 13-hour day shift on the COVID-19 ICU at the University Hospital of Innsbruck, Austria. Blood samples were obtained before putting on the PPE, and after 5 h (12 p.m.), 9 h (4 p.m.) and 13 h (8 p.m.) of working in the contaminated area. The test person was a non-smoker in a healthy condition, with a balanced diet, and regular physical activity. Consistent with common practice on the COVID-19 ICU at the University Hospital of Innsbruck, an FFP3 mask with an exhalation valve (3M™ Aura™ 1873V + NR D, EN149:2001 + A1:2009) was used.

Radial arterial puncture was performed both right and left. The laboratory-chemical examination was carried out directly after sampling at the COVID-19 ICU.

After removing the contaminated clothing for a break of 20 min at 12:30 p.m., a new FFP3 mask of the same type was put on. For the evaluation of gas exchange, particular attention was given to partial pressure of oxygen (PaO_2) and partial pressure of carbon dioxide ($PaCO_2$). The measurement at 7:00 a.m. served as a baseline before donning the PPE.

Before blood sampling collection, consent of the test person to participate was obtained. There was no need for ethical approval.

RESULTS

The results of the respective measurements are depicted in Figure 1. A continuous decrease in PaO_2 in the course of the day shift was detectable. Compared to the baseline PaO_2 (102.0 mm Hg), a reduction of 20.8% was observed after a 13-hour day shift.

Concerning the ventilation, an increase in $PaCO_2$ with a maximum value of 38.9 mm Hg was noticeable. This means an increase of 32.8% in comparison to the baseline $PaCO_2$ (29.3 mm Hg).

DISCUSSION

The present project deals with the fundamental question of whether PPE has an impact on the health of staff members. The author assessed the effects in a structured self-experiment ("N-of-1-trial") by regular arterial blood samplings in a healthy volunteer. At the University Hospital of Innsbruck, FFP3 masks (3M™ Aura™) with exhalation valves were supplied by the hospital operator (Tirol Kliniken GmbH, Innsbruck, Austria) for daily work at the COVID-19 ICU. Hence, this type of a mask was also used for the conducted investigation. According to the manufacturer (3M, St. Paul/Minnesota, USA), the exhalation valve lowers the breathing resistance.

Except for 1 break of 20 min, during which the test person left the COVID-19 ICU, the mask was tight-fitted in the best possible way. The collected data shows a trend towards the possible influence of a typical FFP3 mask on oxygenation and ventilation during a multi-hour wearing time under regular working conditions. Measurable changes in both parameters were obvious, although an exhalation valve for diminished exhalation resistance was integrated. All measured values were within the normal range, but a trend towards an insufficient gas exchange could be suspected.

The question of potential physical effects of wearing a face mask gives grounds for fundamental research. Concerning the use of surgical masks, significant clinical effects on gas

exchange, even in subjects with severe lung impairment, were already precluded [5]. Fikenzer et al. [4] focused, in a prospective cross-over study, on the impact of wearing different types of face masks on the cardiopulmonary capacity of healthy individuals. Their findings, based on ergo-spirometry and impedance cardiography, showed a high impairment caused by FFP2/N95 masks in ventilation, cardiopulmonary exercise capacity and comfort.

Besides, the results presented in this article are in line with a prior trial of 10 healthcare professionals wearing N95 filtering face piece respirators for multiple 1-hour treadmill walking sessions [6]. Transcutaneously measured $PaCO_2$ values were elevated in some subjects. Furthermore, dead-space CO_2 and O_2 levels were significantly affected. The results illustrate that an effect on gas exchange occurs after a comparatively short wearing time. These findings should be borne in mind, as the effectiveness of respirators in healthcare settings might depend on their continual use during a shift [7].

CONCLUSIONS

The data described is the result of a single pilot testing. To substantiate the consistency of these observations, more data is needed. The presented research method and results might be of interest for future randomized larger trials comparing several types of FFP3 masks with regard to their effects on gas exchange.

So far, an effect of wearing an FFP3 mask, even with an integrated exhalation valve, on gas exchange under routine circumstances on the ward, can be assumed. These physiological burdens should absolutely be considered when organizing the healthcare professional team, particularly with regard to preexisting conditions, regular breaks and recovery time.

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