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IS WEARING A N-95 MASK FOR LONG DURATIONS IN THE OUT-PATIENT DEPARTMENT AND OPERATING THEATRE HARMFUL TO THE SURGEONS?

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ABSTRACT

Background: The COVID-19 pandemic, is a pandemic in progress! There is a general consensus that all health-care workers should wear N-95 masks and gloves for all patient interactions. The primary purpose of this study was to determine the physiological burdens on a surgeon of wearing N-95 masks throughout the day.

Methods: We conducted an observational prospective study among 25 healthy orthopaedic surgeons at our centre. Heart rate, oxygen saturation, respiratory rate and end-tidal carbon dioxide ($ETCO_2$) of the surgeons were measured using a vitals-parameter patient-anaesthetic monitor at the start and end of the day on 3 consecutive days in two different scenarios; i.e., (a) Out-patient department (b) Operating theatre.

Results: All the orthopaedic surgeons taking part in the study were males, with a mean age of 32.64 years. In both scenarios, there was an average increase of 4.74 mmHg in $ETCO_2$ and this was found to be statistically significant (p-value <0.001). However, we did not notice any clinical manifestations of the same in either of the surgeons during the duration of the study. We were unable to establish any statistically significant variations among the other vital parameters recorded during the study.

Conclusion: This study recognized a significant rise in ETCO2 (within normal limits) on using the N-95 masks, without any clinical manifestations. Therefore, usage of these masks during all patient-interactions should be continued, as there are no ill-effects with prolonged use throughout the day.

KEYWORDS : COVID-19, End-tidal carbon di-oxide, ETCO2, N-95 mask, Prolonged Use, Surgeon

INTRODUCTION

A novel coronavirus (SARS-CoV-2) that came to light in the late 2019 gave rise to a world-wide pandemic and was labelled a public health emergency by the World Health Organization (WHO) [1,2]. Concerns over emerging air-borne infectious diseases have previously highlighted the importance of respiratory protection among health care workers, and the recent emergence of the coronavirus disease (COVID-19) warrants using respiratory protective equipment (RPE) especially among the health care workers. Respiratory protection in healthcare settings is generally accomplished by engineering and administrative controls, of which the most commonly recommended and used are the N-95 filtering facepiece respirators (FFRs). It is mandatory for health care workers who care for COVID-19 patients to employ personal protective equipment as they are at a greater risk of contracting the disease, and therefore respiratory protective equipment is often worn for very long durations throughout the day. Now, with the relaxation of lockdown and re-starting of out-patient services & elective surgeries among patients who are not infected, health care workers are required to wear such respirators and medical masks for hours at a time.

There is a paucity in literature with respect to the physiological burden accompanying the use of FFRs, which raises multiple queries on the safety of wearing FFRs for prolonged durations of time. We now know that beneath the surgical masks, heat and moisture trapping occurs and therefore it is safe to presume that a portion of the exhaled CO_2may also be trapped, prompting a decrease in blood oxygenation. Theoretically, there may be an increase in breathing resistance with extended wear, due to exhaled moisture entrapment within the masks [3]. The operating theatres, as a rule, maintain the universal air-conditioning standards, as it is common knowledge on its beneficial effects of ambient environment enhancing the mental and physical performance of the surgeon. However, the "personal" aspect of the surgeon is not adequately factored in, as a result of which it is not uncommon for the surgeons to experience discomfort and fatigue that can sometimes, even affect the quality of surgical judgement and performance. Similar circumstances are faced by surgeons in the out-patient department while examining patients on a daily basis during the COVID-19 pandemic.

Despite widespread use of N-95 masks, there is very little rigorous scientific data with respect to the physiological impact of FFRs on healthcare workers. The aim of this study was to determine the physiological burdens of wearing a N-95 mask by a surgeon in two different scenarios, i.e., in the out-patient department and during surgery. We hypothesized that there will be variations in vital parameters during the course of the day on wearing a N-95 mask in both scenarios, however it will not cause any harm or ill-effects to the surgeon in-spite of long-term use throughout the day.

MATERIALS AND METHODS

An observational prospective study was conducted among the orthopaedic surgeons at a tertiary hospital. Prior ethical clearance was obtained from the Institutional Human Ethics Committee, Ref: Project No: 1/F/2021. Surgeons who tested positive for COVID-19 or showed symptoms mimicking that of COVID-19 were excluded from the study. Surgeons with any known medical co-morbidities were also excluded from the study. Twenty-five surgeons took part in the study. All surgeons wore N-95 masks of the same manufacturer (VENUS *V*-4400 Flat Fold, NIOSH Approved Respirator) during OPD hours and during surgery. The parameters were noted during the study using a vitals parameter patient monitor. The same monitor (Nihon-Kohden), was used to measure the parameters of all 25 surgeons. The parameters noted were; heart rate (HR), oxygen saturation (SpO_2), respiratory rate (RR) and end-tidal carbon-dioxide volume ($ETCO_2$). These parameters were noted in two different scenarios on 3 consecutive days;

1. In the Outpatient department: The parameters were noted at the start of the day before OPD and at 2 hours after start of OPD as depicted in **Figure 1**. The surgeon was instructed not to remove the N-95 mask during this duration.

2. In the Operating theatre: The parameters were noted prior to start of surgery and immediately after the surgery was over as depicted in **Figure 2.** The duration of surgery ranged from 1 hour 45 minutes to 2 hours.

The above-mentioned vital parameters were noted for a surgeon for 3 consecutive days in the OPD, followed by, the next 3 consecutive days in the operating theatre. The parameters for all 25 surgeons were

documented in the same manner as mentioned above. The parameters were measured and documented by the author (Orthopaedic surgeon), who did not take part in the study. The data was entered in excel and analyzed using SPSS-27 software. Categorical variables were presented as frequency and percentages, Continuous variables were presented as Mean ± Standard deviation. Wilcoxon Signed Rank test was used to measure the association between the vitals at different times. P<0.05 was considered as statistically significant.

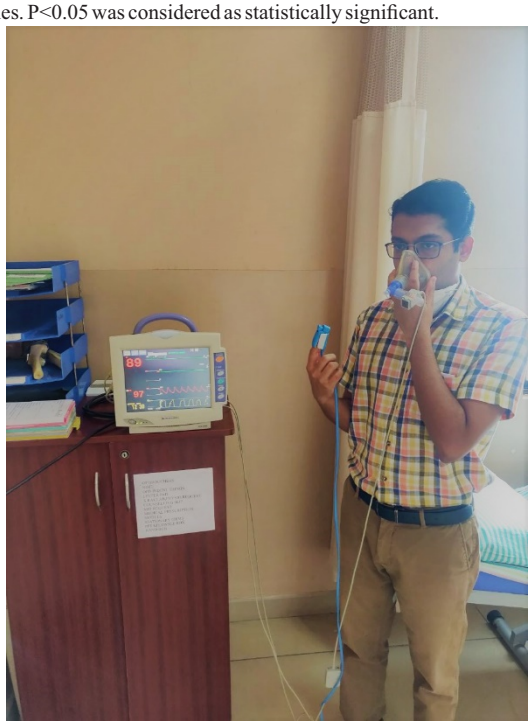

Figure 1 - The image depicts vital parameters being documented in the OPD

Figure 2 - The image depicts vital parameters being documented in the Operating theatre

RESULTS

A total of 25 orthopaedic surgeons took part in the study which included 5 Senior consultants and 20 Associate consultants. All 25 surgeons were males with a mean age of 32.64 years. In the OPD setting (first scenario; duration 2 hours), we noticed a rise in heart rate at the end of OPD on Day 1. However, this finding was not noticed over the next two days. There was no statistically significant change in respiratory rate and oxygen saturation on either of the 3 days. We noticed a statistically significant rise in end-tidal carbon dioxide (ETCO2) levels at the end of the OPD which was consistently noted on all 3 days, as depicted in **Figure 3.** There was an average increase in ETCO2 of 4.91 mmHg at the end of 2 hours in OPD.

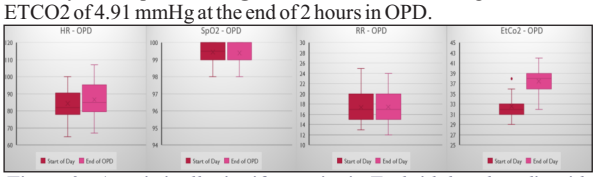

Figure 3 - A statistically significant rise in End-tidal carbon di-oxide was noted on all 3 days in the OPD

In the operating theatre (second scenario), the duration of surgery ranged from 1 hour 45 minutes to 2 hours. The mean duration for surgery was 1 hour 55 minutes. There was no significant rise in heart rate, respiratory rate and oxygen saturation of the operating surgeon post-operatively on either of the 3 days. However, similar to the OPD findings, there was a statistically significant rise in $ETCO_2$ values for all 25 operating surgeon post-operatively on all 3 days as depicted in **Figure 4**. There was an average increase in $ETCO_2$ of 4.57 mmHg at the end of surgery. In both scenarios, there was a statistically significant rise (mean rise of 4.74 mmHg) in $ETCO_2$ for all the surgeons on 3 consecutive days in both scenarios, i.e., in the OPD and operating theatre as shown in **Table 1**.

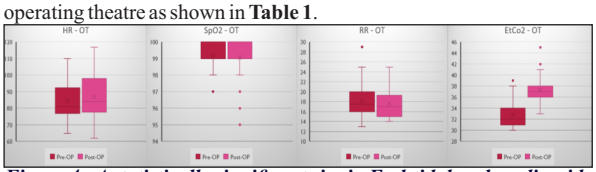

Figure 4 - A statistically significant rise in End-tidal carbon di-oxide was noted in the Operating theatre, similar to the findings in the OPD

DAY	Time Of Day	MEAN	SD	Mean Diff	Z- Value	P- Value
HR* - OPD*						
DAY 1	Start	83.21	9.97	2.21	-2.348	0.019
	End	85.42	9.19			
DAY 2	Start	84.42	8.94	2.08	-1.612	0.107
	End	86.5	10.86			
DAY 3	Start	85.5	7.31	2.42	-1.605	0.108
	End	87.92	9.36			
$ETCO_2$* - OPD						
DAY 1	Start	32.5	2.27	5.0	-3.321	0.001
	End	37.5	2.17			
DAY 2	Start	32.92	2.2	5.08	-3.315	0.001
	End	38	2.32			
DAY 3	Start	32.35	1.54	4.65	-3.309	0.001
	End	37	2.07			
$ETCO_2$ – OT*						
DAY 1	Start	32.78	2.8	4.14	-3.246	0.001
	End	36.92	2.09			
DAY 2	Start	33.14	1.7	4.57	-3.329	0.001
	End	37.71	1.63			
DAY 3	Start	32.42	2.06	5	-3.306	0.001
	End	37.42	3.05			

Table 1. An increase in HR was noted on Day 1 in OPD, however, this finding was not consistent on all 3 days and was not considered to be significant. We noted a statistically significant increase in $ETCO_2$ among all 25 surgeons on all 3 days in both scenarios.

DISCUSSION

End-tidal CO_2 ($ETCO_2$) is referred to the maximum expired CO_2 at the end of a respiratory cycle. It is regarded as an indirect measurement of the alveolar concentration of CO_2 ($ETCO_2$) which closely represents arterial CO_2 ($PaCO_2$) levels in a healthy patient [4]. There are two preferred methods for monitoring $ETCO_2$; either by colorimetric or capnometry. Colorimetry utilizes a pH strip to measure the exhaled CO_2 which is a semi-quantitative measurement of the $ETCO_2$ [5]. The pH strip changes colour proportionate to the concentration of exhaled CO_2. On the other hand, capnometry involves uninterrupted quantitative computations of expired air and the measured CO_2 concentration is depicted graphically and/or numerically. There are multiple advantages of Capnometry; it is a non-invasive, continuous monitoring method which can accurately assess ventilation by providing a real-time estimate of $PaCO_2$ [6]. The CO_2 in every exhaled breath is picked up by the monitor and represented in CO_2 concentration over time. A hike in $ETCO_2$ typically indicates an increase in $PaCO_2$ [7]. It may also indicate an increase in production,

inadequate ventilation, or equipment failure.

CO_2 narcosis is the most severe manifestation amongst a broad spectrum of diseases caused due to hypercapnia, a state of heightened serum CO_2. The delineating hallmark of CO_2 narcosis is a decline in the level of consciousness. Inhalation of 1-2% of CO2 for an approximate duration of 17 to 32 mins has shown to marginally elevate blood pressures [8]. Inhalation of 2-3% of CO2 has been known to cause sweating and headache in certain cases [8]. Inhalation of 4-5% of CO2 can cause dyspnea within few minutes and if exposed for a longer duration, may manifest as increased blood pressures, dizziness and headaches [9,10]. If inhaled CO2 concentrations are at 5%, mental depression can arise within several hours [10,11]. The use of N-95 masks has been closely linked with physiological disturbances, which may include, sensations of discomfort; or an escalation in breathing reistance; increase in heart and respiratory rate; profuse facial sweating; and variations in CO2 retention [12,13]. CO2 which is expelled during exhalation, is conserved within the dead space of the N-95 masks and is eventually re-breathed with successive inhalations [14]. Human studies have shown that, there is no distinction in the volume of dead space CO2 between N-95 masks with and without an exhalation valve [15]. This study has used N-95 masks without an exhalation valve of the same manufacturer among all the study participants. We noticed a consistent rise in $ETCO_2$ (within the normal limits) for all 25 surgeons both in the out-patient department and in the operating theatre after a minimum duration of 2 hours. However, none of the surgeons experienced symptoms suggestive of CO_2 narcosis such as headache, dizziness, confusion or depressed levels of consciousness. This study was unable to establish a statistically significant variation with other vital parameters such as heart rate, respiratory rate and oxygen saturation. This finding is similar to another study which reached a conclusion that an increase in cardio-pulmonary parameters while wearing N-95 masks at low work rates is most likely linked to the work itself, rather than the respirator mask [16].

The main aim of this study was to determine the physiological impact of wearing n-95 masks for long periods of time throughout the day. In a similar study by Rhee et. al, the CO_2 levels were measured in 11 healthy volunteers using different types of N-95 masks. This study noted a significant increase in CO_2 concentrations with routinely used face-masks, within the NIOSH (National Institute for Occupational Safety and Health) limits and deemed the masks safe for regular day-to-day use [17]. Roberge et. al assessed the physiological impact of N-95 FFR on 10 health care workers on multiple 1-hour treadmill walking sessions. The study concluded that in healthy healthcare workers, the FFR did not impose any physiological burden during its use. However, the FFR dead-space carbon dioxide was significantly raised, in which, elevated PCO_2 is a possibility [18]. Beder et al. carried out a study, to determine if the oxygen saturation levels were affected by wearing a surgical mask during major surgery. They revealed a reduction in the oxygen saturation of arterial pulsations ($Sp0_2$) and with a slender increase of pulse rates in comparison to pre-operative values in all surgeon groups [19]. There is still very limited data with respect to the physiological and psychological impact of FFR, regardless of its comprehensive usage over the last few decades [20,21].

This study is however not without any limitations. The study population involved surgeons who are relatively young, with a mean age of 32.64 years. Variations in vital parameters with N-95 masks usuage and its association with age has not been accounted for in this study. The tests done in the operating theatre are not after unifrom periods. Some surgeries lasted a little more than 2 hours. The average operating time was noted to be 1hour and 55minutes.

CONCLUSION

We hypothesized that the vital parameters would increase over long durations wearing a N-95 mask within its normal range, but it would not be a psychological burden to the surgeon. In this study; heart rate, oxygen saturation and respiratory rate did not show any significant variations with prolonged use of N-95 masks. There was a statistically significant increase in end-tidal carbon dioxide ($ETCO_2$), which was consistent among all the surgeons. However, the variation was well within the normal range and did not manifest clinically.

To the best of our knowledge, there is no other previous study which has evaluated the vital parameters of surgeons over long durations of time throughout the day, wearing a N-95 mask. This study has helped us come to the conclusion that usage of N-95 masks for long durations in the operating theatre or in the out-patient department has minimal effect of the surgeon's vital parameters and is not dangerous.

Conflict Of Interest- NIL

The authors declare that they have no competing interests.

Funding- NIL

Ethical Approval

Prior to the start of the study, ethical clearance was obtained from the Institutional Human Ethics Committee (IHEC) during the meeting which was held on 21/02/2021. (Ref: Project No: 1/F/2021)

Informed Consent

Informed consent as per IHEC guidelines was obtained from all 25 surgeons participating in the study.

Author Contributions

Each named author has substantially contributed to conducting the underlying research and drafting this manuscript. Additionally, the named authors have no conflict of interest, financial or otherwise.

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REFERENCES

1. Liebensteiner MC, Khosravi I, Hirschmann MT, Heuberer PR, Thaler M. Massive cutback in orthopaedic healthcare services due to the COVID-19 pandemic. Knee Surgery, Sports Traumatology, Arthroscopy. 2020 Jun;28(6):1705-11.
2. Thaler M, Khosravi I, Hirschmann MT, Kort NP, Zagra L, Epinette JA, Liebensteiner MC. Disruption of joint arthroplasty services in Europe during the COVID-19 pandemic: an online survey within the European Hip Society (EHS) and the European Knee Associates (EKA). Knee Surgery, Sports Traumatology, Arthroscopy. 2020 Jun;28(6):1712-9.
3. Khaw KS, WD NK, Tam YH, Wong MK, Lee SW. Survey and evaluation of modified oxygen delivery devices used for suspected severe acute respiratory syndrome and other high-risk patients in Hong Kong. Hong Kong medical journal= Xianggang yi xue za zhi. 2008 Oct 1;14(5 Suppl):27-31.
4. Langhan ML, Chen L. Current utilization of continuous end-tidal carbon dioxide monitoring in pediatric emergency departments. Pediatric emergency care. 2008 Apr 1;24(4):211-3.
5. Andrews FJ, Nolan JP. Critical care in the emergency department: monitoring the critically ill patient. Emergency medicine journal. 2006 Jul 1;23(7):561-4.
6. Ward KR, Yealy DM. End‐tidal carbon dioxide monitoring in emergency medicine, part 2: clinical applications. Academic Emergency Medicine. 1998 Jun;5(6):637-46.
7. Sullivan KJ, Kissoon N, Goodwin SR. End-tidal carbon dioxide monitoring in pediatric emergencies. Pediatric emergency care. 2005 May 1;21(5):327-32.
8. Schneider EC, Truesdell D. The effects on the circulation and respiration of an increase in the carbon dioxide content of the blood in man. American Journal of Physiology-Legacy Content. 1922 Dec 1;63(1):155-75.
9. Patterson JL, Heyman A, Battey LL, Ferguson RW. Threshold of response of the cerebral vessels of man to increase in blood carbon dioxide. The Journal of clinical investigation. 1955 Dec 1;34(12):1857-64.
10. Schulte JH. Sealed environments in relation to health and disease. Archives of Environmental Health: An International Journal. 1964 Mar 1;8(3):438-52.
11. Consolazio WV, Fisher MB, Pace N, Pecora LJ, Pitts GC, Behnke AR. Effects on man of high concentrations of carbon dioxide in relation to various oxygen pressures during exposures as long as 72 hours. American Journal of Physiology-Legacy Content. 1947 Nov 30;151(2):479-503.
12. Baig AS, Knapp C, Eagan AE, Radonovich Jr LJ. Health care workers' views about respirator use and features that should be included in the next generation of respirators. American journal of infection control. 2010 Feb 1;38(1):18-25.
13. Guo YP, Yi L, Tokura H, Wong TK, Chung JW, Gohel MD, Leung PH, Newton E. Evaluation on masks with exhaust valves and with exhaust holes fromphysiological and subjective responses. Journal of physiological anthropology. 2008 Mar 31;27(2):93-102.
14. Roberge RJ. Are exhalation valves on N95 filtering facepiece respirators beneficial at low-moderate work rates: an overview. Journal of occupational and environmental hygiene. 2012 Nov 1;9(11):617-23.
15. Roberge RJ, Coca A, Williams WJ, Palmiero AJ, Powell JB. Surgical mask placement over N95 filtering facepiece respirators: physiological effects on healthcare workers. Respirology. 2010 Apr;15(3):516-21.
16. Kim JH, Benson SM, Roberge RJ. Pulmonary and heart rate responses to wearing N95 filtering facepiece respirators. American journal of infection control. 2013 Jan 1;41(1):24-7.
17. Rhee MS, Lindquist CD, Silvestrini MT, Chan AC, Ong JJ, Sharma VK. Carbon dioxide increases with face masks but remains below short-term NIOSH limits. BMC Infectious Diseases. 2021 Dec;21(1):1-7.
18. Roberge RJ, Coca A, Williams WJ, Powell JB, Palmiero AJ. Physiological impact of the N95 filtering facepiece respirator on healthcare workers. Respiratory care. 2010 May 1;55(5):569-77.
19. Beder A, Büyükkoçak Ü, Sabuncuoğlu H, Keskil ZA, Keskil S. Preliminary report on surgical mask induced deoxygenation during major surgery. Neurocirugia. 2008 Jan 1;19(2):121-6.
20. Harber P, Bansal S, Santiago S, Liu D, Yun D, Ng D, Liu Y, Wu S. Multidomain subjective response to respirator use during simulated work. Journal of occupational and environmental medicine. 2009 Jan 1;51(1):38-45.
21. Bansal S, Harber P, Yun D, Liu D, Liu Y, Wu S, Ng D, Santiago S. Respirator physiological effects under simulated work conditions. Journal of occupational and environmental hygiene. 2009 Mar 3;6(4):221-7.