Available Online at https://www.nepjol.info/index.php/IJOSH
International Journal of Occupational Safety and Health, Vol. 12 No. 3 (2022), 163 – 170

Real work experiences, practices, and adverse events associated with long term usage of N95 respirators during the COVID-19 pandemic – A cross-sectional survey amongst Indian physicians

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ABSTRACT

Introduction: Doctors are at increased risk of exposure to the SARS-CoV-2 virus, and the use of N95 respirators has emerged as a critical preventive measure. We studied the real-world experiences, practices, and adverse effects of N95 respirator usage amongst Indian physicians.

Methods: We conducted an analytical, cross-sectional online survey between November 2020 and January 2021. Real-world usage characteristics of N-95 respirators were collected via a pre-validated questionnaire and compared amongst different sub-cohorts.

Results: A total of 453 responses from physicians were analyzed. The most important adjunct to the N95 respirator perceived by the respondents was the full-face shield (81.9%). Most doctors had to purchase extra masks per month (median = 5 ± 8), which was more among the medical specialties (p = 0.006). The highest mean VAS scores for adverse events reported were for breathing on exertion (6.62 ± 2.25) and ear pain (6.34 ± 2.69). VAS ear pain was higher in ages ≤ 40 and doctors working in the public sector (p = 0.017 and p = 0.019 respectively).

Conclusion: Despite many inadequacies regarding proper mask removal, doffing techniques, and multiple reported prolonged mask usage-related adverse effects, there is generally good adherence to protocols and good practices of mask usage amongst physicians in the hospital setting.

Key words: Adverse effects; COVID-19, India, N95 respirator, Personal Protective Equipment

DOI: https://doi.org/10.3126/ijosh.v12i3.41915

Conflicts of interest: None
Supporting agencies: None

Date of submission: 29.12.2021
Date of acceptance: 23.01.2022
Date of publication: 01.07.2022

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INTRODUCTION

Since the first detection of Coronavirus disease 2019 (COVID-19) and its evolution into a global pandemic, public health measures preventing the spread of the disease have come to the forefront. COVID-19 is caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), transmitted mainly via respiratory droplets during close face-to-face contact.[1] Thus, one of the essential measures in preventing the airborne spread of the virus is the usage of medical masks.[2]

Given the increased risk of exposure to SARS-CoV-2 in health care setups, the usage of masks amongst doctors and healthcare professionals has become mandatory worldwide.[3] With increased production and awareness of the increased effectiveness, usage of N95 respirators has become a daily practice amongst doctors.[4,5] The use of an N95 respirator is recommended particularly in an in-patient setting and in the situation of aerosol-generating procedures (AGPs) like intubation, non-invasive positive pressure ventilation, bronchoscopy, tracheotomy and sputum induction; when treating suspected or confirmed COVID-19 patients.[3,6] In addition to mask type, to prevent viral spread, proper mask doffing, removal, and mask disposal practices should also be practiced among healthcare professionals.[7] It must be emphasized that adjuncts to wearing an N95 respirator such as gloves, goggles, face shield and gown, which are other components of Personal Protective Equipment (PPE), are integral to providing complete protection.[8] While these are the recommendations, the real-world practices and experiences with mask usage, especially in a resource-limited setting like India, need to be seen. When SARS-CoV-2 began to spread across the world initially, the fact that N95 respirators were in short supply was a disadvantage. Amongst the strategies developed to bridge this gap was namely sterilization and reuse. Studies have shown that sterilization results in safe reuse.[9] However, data about the real-world experience with mask sterilization is lacking. Another commonly seen practice is the dual-mask technique - with a surgical mask over the N95 respirator, which has closed this gap.[10] It is essential to analyze these practices of N95 use to ensure that the proper techniques are adopted. Also, increased protection offered by masks is not without its drawbacks. There are adverse effects of prolonged mask use in healthcare workers of the pandemic, such as headaches, breathing difficulty, contact dermatitis, halitosis, ear pain and even impaired cognition.[11] However, these adverse events are not uniform and are highly individual dependent.

With this background, we conducted a rapid online survey between November 2020 and January 2021 to study the real-world practices of mask usage amongst Indian doctors during this COVID-19 pandemic. This study aimed to describe their experiences and analyze commonly reported adverse events with mask usage.

METHODS

As the primary objective, we carried out an analytical cross-sectional, online survey to evaluate doctors' real-world experiences and mask usage practice during the COVID-19 pandemic. For this purpose, we created a semi-structured questionnaire using Google Surveys, and it was sent to the contacts of all the investigators using WhatsApp Messenger (Meta, Inc., USA). We collected respondent details related to four domains. Domain 1 had general questions related to age, gender, and job profile (region of work, private or government sector, and seniority level). Domain 2 had questions about hospital-related mask usage concerning mask procurement, usage per day, sterilization methods, and individual routine with additional protection (shields, goggles, gloves). Domain 3 was based on five mask-usage-related adverse events (breathing difficulty at rest and exertion, bad breath, contact dermatitis and ear pain). Each respondent's severity of the adverse events in this domain was scored using a Visual Analog Scale (VAS) ranging from 0 to 10. Domain 4 aimed to assess individual practices with mask usage for each respondent. We assessed mask-wearing techniques (doffing and removal, dual mask-wearing) using multiple-choice questions in addition to mask disposal practices. Also, in this domain, we used a single real-life scenario with subdomains analyzing the frequencies of these practices. All subdomains had four response categories each (for frequency) and were labeled as nil, 25%, 50% and more than 75% of the time. The complete questionnaire is shown in Appendix 1.

After completing the initial draft of the survey questionnaire, it was validated[1] and adopted as follows: firstly, the questionnaire was sent to four academic experts knowledgeable in the area. After coordination and consensus of all experts' opinions, the final questionnaire was drafted and underwent pilot testing in 30 individuals to confirm the reliability of the questionnaire. The data from the pilot study were loaded into SPSS version 21 and subjected to reliability coefficient analysis. A minimum sample size of 90 was recommended.

We included the following doctor online forums: i) regional forums of the national medical association, ii) resident and student associations, and iii) alumni forums from the investigator institute, which had included both interns and residents along with junior

and senior doctors. We excluded data from the participants who were practicing outside of India. The request to participate was sent thrice at an interval of 1 week. Consent was taken from all participants at the beginning of the questionnaire, and it was an anonymous survey. Ethical clearance was granted by the Institutional Review Board of Amrita Institute of Medical Sciences vide ref. IRB-AIMS-2020-285.

Data were obtained from Google sheets and analyzed using IBM SPSS® Statistics version 21. Continuous data were summarized using mean and standard deviation between the various subgroups (age > 40 versus ≤ 40 years; males versus female interns; doctors in private versus government sector; medical versus surgical doctors). Categorical data between the same groups were presented as frequency count (n) and percentages (%). After using a Shapiro-Wilk test to identify non-normally distributed continuous data, it was described using median ± interquartile range (IQR), and the various subgroups were compared using the Mann-Whitney U test. Normally distributed data were described as mean ± standard deviation (S.D), with comparisons performed using an unpaired t-test. A p-value of < 0.05 was assigned as statistically significant.

RESULTS

Overall, the questionnaire was distributed to 712 potential respondents. Four hundred ninety-one respondents completed the entire survey, generating a response rate of 69%. After excluding the respondents from outside India, we included 453 responses in the final analysis.

The age group with maximum frequency was in the range of 31-40 years (44.6%), and the gender of the respondents was slightly more for males (53.2%). The medical specialty was most represented (67.3%). Most of the respondents had already reached a higher level of seniority with the maximum frequency obtained in the professors and senior consultants group (40.2%). The majority of the doctors were from the private sector (75.7%), and almost all of them were practicing in South India (94.5%). The detailed baseline characteristics are described in Table 1.

The most important adjunct to the N95 respirator perceived by the respondents was the full-face shield (81.9%). Most doctors used a single N95 mask per day (82.5%). 327 (72.2%) of the doctors sterilized and reused their masks, demonstrating the study population's understanding of optimization of mask usage. The most common methods used for sterilization were air drying (71.5%) and Ultraviolet sterilization (48%), which are the recommended methods in use currently. The mean number of cycles the N95 masks were sterilized and reused was 3.07 ± 1.95 cycles. Most respondents received a median of 5 masks given by their hospital per month (IQR 4-10) and they needed to purchase a median of 5 extra masks (IQR 2-10). 70% of doctors stated that their hospital gave them masks. Summary of Domain 2 responses are detailed in Table 2.

The adverse effect with the highest VAS score of 6.62 ± 2.25 was breathing difficulty on exertion. The next highest was the ear pain VAS score, which received an average severity response of 6.34 ± 2.69 - this is definitely above a moderate level of irritation. All adverse effects are described in Table 3.

Figure 1 depicts the respondent's hospital-related mask usage practices (Domain 4) with the real-life scenario of drinking a glass of water which was analyzed with the frequency at which three maneuvers were done.

The majority of respondents gave a response of pulling the mask down to the neck, removing the mask and keeping the mask dangled to one ear- less than 50% of the time. The most commonly done maneuver was removing the mask entirely while drinking water which 35.1% of total respondents did more than 50% of the time. A majority of physicians disposed of the masks, after usage, in their workplace; however, a third of them reported incorrect practices during this disposal (Figure 2).

Tables 4 and 5 show a comparison between selected domains (quantitative mask usage, workplace supply and severity of adverse events) between specific subgroups - age (more than 40 years and less than or equal to 40 years), gender (male and female), work sector (public and private) and sub-specialty (medical versus surgical). Higher VAS ear pain score was reported in the respondents in the age ≤ 40 years group and doctors working in the public sector ($p = 0.017$ and $p = 0.019$, respectively).

Table 1: Baseline characteristics of respondents (Domain 1).

Age (n,%)	
21-30 years	94 (20.8%)
31-40 years	202 (44.6%)
41-50 years	107 (23.6%)
51-60 years	31 (6.8%)
60-70 years	15 (3.3%)
> 70 years	4 (0.9%)
Sex (n, %)	
Male	241 (53.2%)
Female	212 (46.8%)
Specialty (n, %)	
Medical	305 (67.3%)
Surgical	103 (22.7%)
Para-clinical	45 (9.9%)
Academic level/Seniority (n, %)	
Students/Residents	100 (22.1%)
Assistant Professor/Junior Consultants	171 (37.7%)
Professor/Senior Consultants	182 (40.2%)
Work Sector (n, %)	
Public	110 (24.3%)
Private	343 (75.7%)
Region of Medical Practice (n, %)	
South India	428 (94.5%)
North India	25 (5.5%)

Table 2: Hospital related mask usage practices (Domain 2)

Most important adjuncts that were used with an N95 respirator (n, %)	**Full-Face Shield – 371 (81.9%)** **Gloves – 55 (12.1%)** **Goggles – 24 (5.3%)** **Gown – 3 (0.7%)**
No of N95 mask used per day (n, %)	One mask per day – 374 (82.5%) Two masks per day – 61 (13.5%) Three masks per day – 11 (2.4%) Four masks per day – 5 (1.1%) More than four masks per day – 2 (0.5%)
Sterilization and reusing the N95 mask (n, %)	Yes – 327 (72.2%) No – 126 (27.8%)
Sterilization methods used (n, %)	
Ultraviolet sterilization	157 of 327 (48%)
Air Drying	234 of 327 (71.5%)
Others (Autoclave, Moist Heat, Chemical sterilization)	42 of 327 (12.8%)
Number of cycles of sterilizing and reusing the mask (mean ± S.D)	3.07 ± 1.95
N95 masks provided by the hospital (n, %)	Yes – 317 No – 136
Masks provided by the hospital per month, (median ± IQR)	5 ± 6
Extra Masks purchased per month, (median ± IQR)	5 ± 8

Table 3. Adverse Events with Mask Usage – Visual Analogue Scale scores (Domain 3)

Breathing difficulty at rest (mean ± S.D)	3.91 ± 2.39
Breathing difficulty on exertion (mean ± S.D)	6.62 ± 2.25
Bad breath (mean ± S.D)	3.87 ± 2.68
Contact Dermatitis (mean ± S.D)	2.74 ± 2.88
Ear pain (mean ± S.D)	6.34 ± 2.69

Table 4. Stratified comparisons for age and gender in Domains 2 and 3.

	Age > 40 years (n = 157)	Age ≤ 40 years (n = 296)	p value	Male (n = 241)	Female (n = 212)	p value
Mask given per month, **median (IQR)**	6 (4,10)	5 (4,8)	0.047*	6 (4,10)	5 (4,6)	0.102
Extra Masks per month, **median (IQR)**	5 (2,10)	5 (2,10)	0.586	5 (2,10)	5 (2,10)	0.142
Breathing difficulty (rest), **mean ± SD**	4.0 ± 2.3	3.81 ± 2.5	0.503	4.10 ± 2.4	3.69 ± 2.4	0.070
Breathing difficulty (exertion), **mean ± SD**	6.76 ± 2.0	6.54 ± 2.4	0.520	6.59 ± 2.3	6.65 ± 2.1	0.873
Bad breath, **mean ± SD**	3.92 ± 2.6	3.84 ± 2.7	0.715	3.95 ± 2.6	3.95 ± 2.7	0.491
Contact Dermatitis, **mean ± SD**	2.56 ± 2.5	2.83 ± 3.0	0.906	2.48 ± 2.6	3.02 ± 3.0	0.101
Ear pain, **mean ± SD**	6.0 ± 2.4	6.51 ± 2.7	0.017*	6.48 ± 2.6	6.17 ± 2.7	0.218

*Statistically significant at an alpha level of 0.05.

Table 5. Stratified comparisons for work sector and sub-specialty in Domains 2 and 3.

	Public (n =110)	Private (n = 343)	p value	Medical (n = 305)	Surgical (n = 103)	p value
Mask given per month, **median (IQR)**	6 (5,20)	5 (4,8)	<0.001*	5 (4,10)	6 (4,8)	0.247
Extra Masks bought per month, **median (IQR)**	5 (3,10)	5 (2,10)	0.853	5 (3,10)	5 (0,10)	0.006*
Breathing difficulty (rest), **mean ± SD**	4.09 ± 2.2	3.85 ± 2.4	0.412	3.84 ± 2.4	4.03 ± 2.9	0.403
Breathing difficulty (exertion), **mean ± SD**	6.91 ± 2.0	6.53 ± 2.3	0.245	6.52 ± 2.2	6.94 ± 1.8	0.419
Bad breath, **mean ± SD**	4.15 ± 2.5	3.78 ±2.7	0.161	3.87 ± 2.8	3.80 ± 2.4	0.975
Contact Dermatitis, **mean ± SD**	2.79 ± 3.0	2.72 ± 2.8	0.965	2.81 ± 2.9	2.76 ± 2.9	0.708
Ear pain, **mean ± SD**	6.86 ± 2.5	6.17 ± 2.7	0.019*	6.48 ± 2.7	6.15 ± 2.5	0.186

*Statistically significant at an alpha level of 0.05.

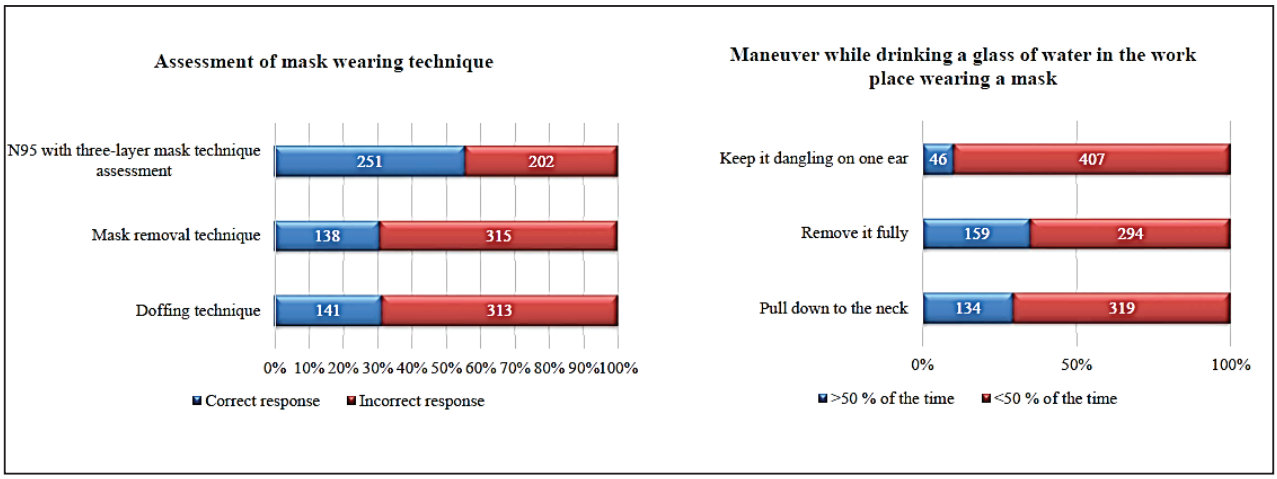

Figure 1: N95 respirator usage practices according to Domain 4 responses

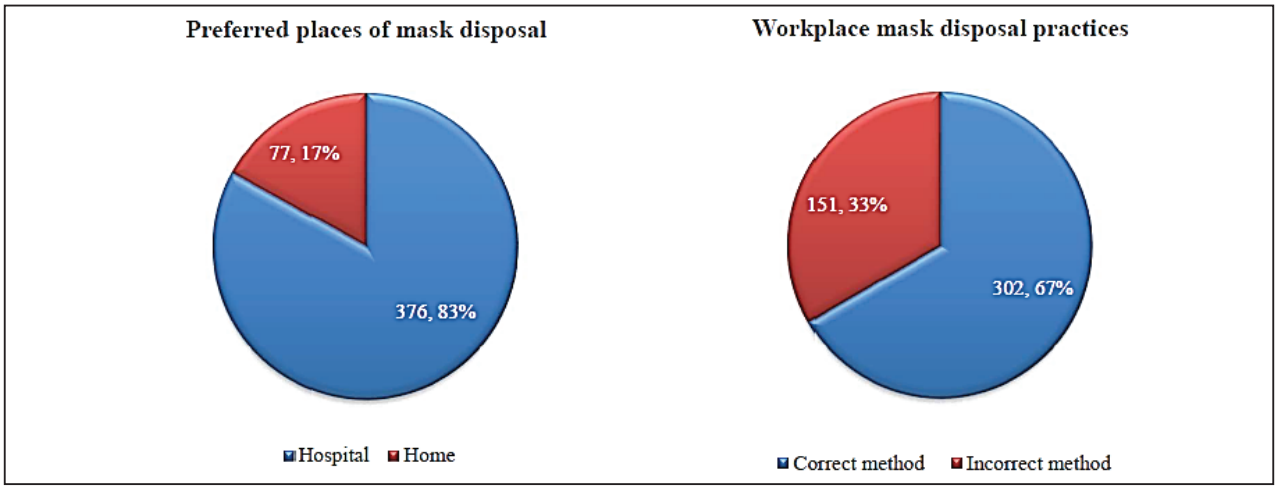

Figure 2: N95 respirator disposal practices according to Domain 4 responses

DISCUSSION

A total of 453 responses from physicians were analyzed. A full-face shield was detected to be the most important adjunct to the N95 respirator. Most doctors had to purchase a median of 5 ± 8 extra masks per month beyond what the hospital provided, and this trend was significantly more among the medical specialties. The highest mean VAS scores for adverse events were reported for breathing on exertion (6.62 ± 2.25) and ear pain (6.34 ± 2.69). VAS ear pain was higher in ages ≤ 40 and doctors working in the public sector ($p = 0.017$ and $p = 0.019$ respectively). Ear pain and exertional breathing difficulty are the most common side effects reported in other populations.[13,14]

Most of the doctors used a single N95 mask per day (82.5%), which has been found acceptable according to current guidelines, provided that it is used for only about 8-12 hours and not soiled or damaged. The mean number of cycles the N95 masks were sterilized and reused was 3.07 ± 1.95 cycles. This practice is comparable in terms of safety to the study by Fischer et al., who state that N95 respirators can be decontaminated and reused up to 3 times in the case of Ultraviolet sterilization and up to 2 times in the case of air drying.[15]

There are many takeaways that the authors note by looking at results from each domain. First, there is good adherence and good practices of mask usage in the hospital setting. The preference to use a face shield as an adjunct is encouraging as studies have shown that face shields worn by the receiver of particles perform better than masks alone in an experience of short face-to-face exposure.[16] Cost-effective practices are being followed, with a high proportion of respondents practicing mask sterilization and reuse. This practice is similar to other studies reported across the world.[17] The fact that most doctors had to purchase at least five masks for use is disheartening. Given the low remuneration of medical professionals in India when compared to Western doctors, the added cost of PPE purchase is yet another burden on medical professionals. An interesting observation on subgroup analysis is that the medical specialties, on average, purchased extra masks than the surgical specialties ($p=0.006$). We presume this is because of the hospital supply of PPE kits (which include masks) as part of operation theatre protocols to the surgeons, who did not require additional masks beyond this usage.

The most alarming responses given by most of the doctors were concerning the mask-doffing and mask removal, where 68.9% of the doctors gave an incorrect response for mask-doffing and 69.5% an incorrect response for mask removal. Such responses given by a majority of the doctors across all the stratifications suggest that there is a definite lack of knowledge in these protocols. It is of paramount importance that these incorrect notions are dispelled, as doffing of the PPE and N95 mask is the highest risk time for self-contamination.[18] The method of wearing an N95 respirator with a surgical mask was also assessed. Though 55.4% of the doctors gave a correct response, many are still unaware of this technique. The survey showed that disposal practices among the doctors were an area where more was known- 83% of doctors preferred to dispose of the masks at the hospital and 66.7% of doctors were aware of the correct disposal method. Proper knowledge of the disposal of N95

masks into “yellow color-coded bags” helps properly segregate and eliminate the contaminated waste so that it does not pose a health risk to others.[19]

Our survey is limited due to a poor response rate and the dispersal of the survey was not entirely homogenous as most of the respondents were practicing in South India. The public sector of the Indian healthcare system was also under-represented in our study, making up a small fraction of the respondents. Thus, a more extensive national survey should be conducted to represent Indian doctors from all parts of the country and both sectors. Greater insight into the mask practices in dedicated COVID wards in hospitals across India is an area where further studies can be done as this is an even more crucial subset of the doctors – where incorrect practices are detrimental to the health of all involved.

CONCLUSION

Our study demonstrates that there are still many inadequacies concerning proper mask removal and doffing techniques among doctors in India. Proper education of the protocols must be done to bridge this gap. The significant adverse effects faced by the doctors on prolonged mask usage were ear pain and breathing difficulty on exertion, which are uniform across all groups. Only the severity of ear pain was reported more in younger doctors. The number of N95 masks given by the hospital is also an issue that needs some improvement from an administrative point of view, as most doctors are purchasing a significant number of masks as an out-of-pocket expense. However, it can be noted that despite these deficiencies, there is generally good adherence to protocols and good practices of mask usage in hospital settings.

REFERENCES

1. Tabatabaeizadeh SA. Airborne transmission of COVID-19 and the role of face mask to prevent it: a systematic review and meta-analysis. Eur J Med Res. 2021 Jan 2;26(1):1.
2. Liang M, Gao L, Cheng C, Zhou Q, Uy JP, Heiner K, et al. Efficacy of face mask in preventing respiratory virus transmission: A systematic review and meta-analysis. Travel Med Infect Dis. 2020 May 28;36:101751.
3. Health workforce policy and management in the context of the COVID-19 pandemic response [Internet]. [cited 2021 May 1]. Available from: https://www.who.int/publications-detail-redirect/WHO-2019-nCoV-health_workforce-2020.1
4. Kim MC, Bae S, Kim JY, Park SY, Lim JS, Sung M, et al. Effectiveness of surgical, KF94, and N95 respirator masks in blocking SARS-CoV-2: a controlled comparison in 7 patients. Infect Dis (Lond). 2020 Dec 1;52(12):908–12.
5. Dau NQ, Peled H, Lau H, Lyou J, Skinner C. Why N95 Should Be the Standard for All COVID-19 Inpatient Care. Ann Intern Med. 2020 Nov 3;173(9):749-51.
6. Klompas M, Baker M, Rhee C. What Is an Aerosol-Generating Procedure? JAMA Surgery. 2021 Feb 1;156(2):113–4.
7. Rubio-Romero JC, Pardo-Ferreira MDC, Torrecilla-García JA, Calero-Castro S. Disposable masks: Disinfection and sterilization for reuse, and non-certified manufacturing, in the face of shortages during the COVID-19 pandemic. Saf Sci. 2020 Sep;129:104830.
8. Mahmood SU, Crimbly F, Khan S, Choudry E, Mehwish S. Strategies for Rational Use of Personal Protective Equipment (PPE) Among Healthcare Providers During the COVID-19 Crisis. Cureus. 2020 May 23;12(5):e8248.
9. Steinberg BE, Aoyama K, McVey M, Levin D, Siddiqui A, Munshey F et al. Efficacy and safety of decontamination for N95 respirator reuse: a systematic literature search and narrative synthesis. Can J Anaesth. 2020 Dec;67(12):1814-23.
10. de Perio MA, Dowell CH, Delaney LJ, Radonovich LJ, Kuhar DT, Gupta N, et al. Strategies for Optimizing the Supply of N95 Filtering Facepiece Respirators During the Coronavirus Disease 2019 (COVID-19) Pandemic. Disaster Med Public Health Prep. 2020 Oct;14(5):658–69.
11. Rosner E. Adverse Effects of Prolonged Mask Use among Healthcare Professionals during COVID-19. J Infect Dis Epidemiol. 2020 Jun 1;6(3):130. doi.org/10.23937/2474-3658/1510130
12. Gupta M, Singh A, Gupta M. An Otorhinolaryngologists Perspective on Using Face Masks by Health Care Professionals Based on an Online Survey. Indian J Otolaryngol Head Neck Surg. 2020 Oct 28:1-6.
13. Al Naam YA, Elsafi SH, Alkharraz ZS, Alfahad OA, Al-Jubran KM, Al Zahrani EM. Community practice of using face masks for the prevention of COVID-19 in Saudi Arabia. PLOS ONE. 2021 Feb 19;16(2):e0247313.
14. Battista RA, Ferraro M, Piccioni LO, Malzanni GE, Bussi M. Personal Protective Equipment (PPE) in COVID 19 Pandemic: Related Symptoms and

Adverse Reactions in Healthcare Workers and General Population. J Occup Environ Med. 2021 Feb 1;63(2):e80–5.

15. Fischer RJ, Morris DH, van Doremalen N, Sarchette S, Matson MJ, Bushmaker T, et al. Assessment of N95 respirator decontamination and reuse for SARS-CoV-2. medRxiv. 2020 Apr 24;2020.04.11.20062018.
16. Wendling JM, Fabacher T, Pébaÿ PP, Cosperec I, Rochoy M. Experimental Efficacy of the Face Shield and the Mask against Emitted and Potentially Received Particles. Int J Environ Res Public Health. 2021 Feb 17;18(4):1942.
17. Scalvenzi M, Villani A, Ruggiero A. Community Knowledge About the Use, Reuse, Disinfection and Disposal of Masks and Filtering Facepiece Respirators: Results of a Study Conducted in a Dermatology Clinic at the University of Naples in Italy. J Community Health. 2020 Nov 30;1–8.
18. Lockhart SL, Duggan LV, Wax RS, Saad S, Grocott H.P. Personal protective equipment (PPE) for both anesthesiologists and other airway managers: principles and practice during the COVID-19 pandemic. Can J Anaesth. 2020 Aug;67(8):1005–15.
19. Sangkham S. Face mask and medical waste disposal during the novel COVID-19 pandemic in Asia. Case Studies in Chemical and Environmental Engineering. 2020 Sep;2:100052