MEDICAL SNORKEL-MASK: A REUSABLE PERSONAL PROTECTIVE EQUIPMENT FOR HEALTH WORKERS

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ABSTRACT

Covid-19 is a new disease caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). The increasing number of cases of Covid-19 has made it difficult for hospitals to handle it, and health workers are at a higher risk of infection by SARS-CoV-2 and urgently need Personal Protective Equipment (PPE) to protect themselves and minimize the spread of the virus. However, the usage of PPE especially face-masks often causes discomfort. Therefore, a new type of face mask has emerged, namely the medical snorkel mask. This mask is designed to cover the entire face and is made by modifying the air circulation section by adding an air filter. The filter used is PALL Ultipor 25 with a HEPA filter capable of filtering up to 0.3 microns in size and has an efficiency of 99.99%. Medical snorkel mask that is used properly are quite efficient in preventing the transmission of Covid-19, with a fitting factor of 142 from pass level 100. This mask also has passed the CO_2 toxicity test. The advantages of a medical snorkel mask include protecting the entire face from infectious droplets, preventing direct hand contact with the face, being reusable, and being equipped with an effective air filter by minimizing the potential for filtrate malfunction. Some of the disadvantages of this mask include interfering with the communication process, cannot being used in conjunction with glasses, a buildup of CO_2, increasing the work of breathing, and limiting vision. However, some of these weaknesses can be minimized by modifying the mask and maintaining an optimal barrier system. Given the high level of effectiveness and efficiency, medical snorkel masks can be a novel solution to overcome the discomfort of using PPE for health workers in Indonesia. Hopefully, it can reduce the morbidity and mortality of health workers due to exposure to Covid-19.

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INTRODUCTION

Coronaviruses are encapsulated RNA viruses, 26-32 kb in size, belonging to the family Coronaviridae, subfamily Coronavirinae (Dhama et al., 2020; Li et al., 2020). The virus is associated with several disease outbreaks such as SARS, MERS, and most recently Covid-19. Covid-19 is caused by the new coronavirus, the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) that causes the symptoms of fever, cough, difficulty breathing, myalgia, and fatigue. Transmission occurs from human to human through direct contact, droplets, and fomites (Dhama et al., 2020).

So far, the number of Covid-19 cases has increased significantly. As of January 27, 2021, Covid-19 cases in the world had

reached 99,864,391 confirmed cases with a death toll of 468,808 people (WHO, 2021). The increase in Covid-19 cases also occurred in Indonesia. As of January 27, 2021, confirmed cases of Covid-19 in Indonesia reached 1,024,298 cases with a mortality of 28,855 people (Covid-19 Task Force, 2021). The increasing number of cases of Covid-19 had made it very difficult for hospitals to handle them so health workers were the main targets for contracting Covid-19.

Therefore, respiratory and eye Personal Protective Equipment (PPE) is considered important in preventing infection in health workers who are in direct contact with Covid-19 patients or their respiratory secretions. PPE standards that must be used by health workers include medical masks, gowns, gloves, and eye protection equipment such as goggles or face shields. However, if carrying out procedures that are prone to producing aerosols in Covid-19 patients, health workers must use additional PPE such as N95/FFP 2 masks and aprons (WHO, 2020).

Almost all of these types of PPE are single-use types which can cause production and supply lines to run out quickly and there may be cross-border transportation difficulties (CDC, 2020). In addition, wearing and removing this PPE properly and correctly takes time. Working with PPE for a long time and repeatedly is also very tiring and can cause facial lesions due to the suppression of PPE in the facial area (Lan et al., 2020).

According to Erdem and Lucey (2020), many health workers were infected and died from Covid-19, even though they have used PPE. On May 8, 2020, 152,888 health workers were reported to be infected with Covid-19 with a death toll of 1,413 out of a total of 270,426 deaths due to Covid-19 worldwide (Bandyopadhyay et al., 2020). This was supported by Gómez-Ochoa et al. (2020) who stated that there about one-tenth of the total health workers in hospitals diagnosed with acute SARS-CoV-2 infection. Meanwhile in Indonesia alone, the death rate of health workers due to Covid-19 reached 682 as of January 29, 2021 (Covid-19 Report, 2021). Based on the description above, the use of PPE needs to be maximized by increasing the comfort of its use. In this paper, we discussed a new PPE breakthrough to increase the comfort of health workers in using it, namely the medical snorkel mask. This mask consists of several components, namely a snorkeling mask, a special adapter, and a filter (Kusano et al., 2020). This medical snorkel mask can protect the eyes and face and are equipped with an air filter (Kroo et al., 2020). It is hoped that this medical snorkel mask can be a promising innovation to overcome the inconvenience of the usage of widely-available PPE so that later it can reduce the rate of transmission of Covid-19 to health workers and reduce the morbidity and mortality of health workers due to exposure to Covid-19.

OVERVIEW

These medical snorkels are full-face scuba masks with additional filters for filtration function. This breakthrough has been approved and used in several countries, including France, Belgium, and Italy in the form of Pneumask as a solution to the lack of PPE at that time (Kroo et al., 2020).

The prototype

The medical snorkel mask was made by modifying the air circulation part by adding a filter. The medical snorkel mask has 2 separate compartments: an upper part for

viewing and a lower part for breathing, it is this respiratory circulation route that is then modified (Kechli et al., 2020). The medical snorkel mask has a full-face main surface structure. The word full-face refers to a design that covers the entire face, including the eyes, nose, and mouth. The structure and design of the medical snorkel-mask before being modified can be described in the following figure:

On the outside, the full-face snorkel mask is composed of polycarbonate or polypropylene material as the main constituent of the glass. To prevent water from entering the mask chamber, waterproof silicone is added to the edges of the mask. This is also to ensure that the mask is securely attached to the user's face. The upper part is the main channel for air entry for breathing (Kroo et al., 2020). In the transition section between the main compartment and the top (air ducts) there are 3 baffles with 1 partition in the middle for the inhalation channel and 2 channels on the lateral side as the exhalation channel (see Figure 2). This is done so that the incoming and outgoing air does not mix thus avoiding CO_2 toxicity (Kechli et al., 2020).

On the inside, the visual and ventilation compartments are separated by a silicone bulkhead to avoid condensation due to respiratory water vapor that may interfere with vision. There is a separate channel for inspiration and expiration. Therefore, the compartment separator bulkhead is equipped with a one-way valve that allows air to enter without being able to return (Kroo et al., 2020). In addition, medical snorkel masks are equipped with a drainage system in the mouth to help expel water vapor and exhaled air (Germonpre et al., 2020).

Filter as the main device

The main modification of the medical snorkel mask is done by providing a filter as an air filter from viruses and other pathogens in the upper air circulation channel. This transition section is not permanently assembled so it is possible to make the modification process easier by adding adapters. The air duct on the top of the mask is replaced with a two-way filter (Kechli et al., 2020).

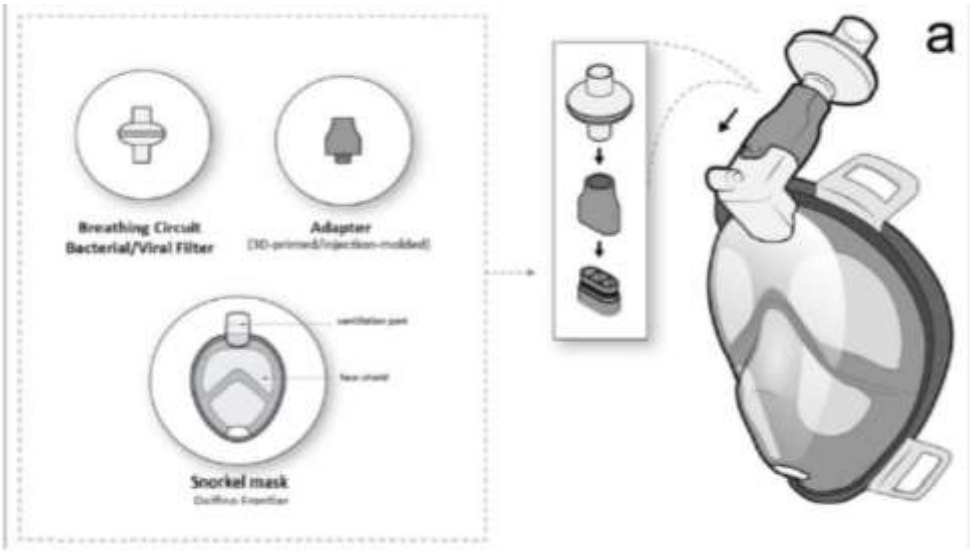

Figure 1 The concept of a medical snorkel-mask as a PPE (Kroo et al., 2020)

Referring to the research results of Kechli et al. (2020), the effective filter that can be used is the PALL Ultipor 25 with HEPA filter. HEPA (High-Efficiency Particulate Air) is a type of mechanical air filter with the ability to filter particles up to 0.3 microns with a 99.99% efficiency rate (O'Kelly et al., 2021). PALL Ultipor 25 will act as the upper airway in the medical snorkel mask. The baffle structure consists of 3 baffles (middle baffle for the inspiratory track and two on the side for the expiratory duct) to separate inspired and expiratory air so it will not cause CO_2 toxicity (Kechli et al., 2020).

Mechanism of Action

During the inspiration phase, air begins to enter the PALL Ultipor 25 filter chamber to be filtered from viral or bacterial contaminants (Kechli et al., 2020). The filtered air will enter the visual compartment through the middle baffles and be forwarded to the respiratory compartment through the one-way valve in the inter-compartmental bulkhead. When the air enters the breathing compartment, the valve will close to block the air from flowing back into the visual compartment. During the expiration phase, the air will leave the respiratory compartment through the drainage channel, passing the one-way valve. Then into the expiratory air duct located on the side of the medical snorkel mask to the side baffles on the snorkel fitting (Kroo et al., 2020); Germonpre et al., 2020). Before being discharged into the free air, the exhaled air will pass through the filter again to be filtered, so that the air that comes out is minimally contaminated (Kechli et al., 2020).

Effectivity and efficiency

Several studies have mentioned the efficiency of these medical snorkel masks. In a study by Kechli, et al. (2020), he compared the effectiveness of the medical snorkel masks with the N95 standard which has good results. The fit test was carried out according to the standards of the United States Occupational Safety and Health Administration (OSHA) N95 respirator (N95), the test obtained a fit factor score of 142 out of 7 exercises performed. However, this figure is still below the fitting factor of N95 masks which reached 200+ from the standard at 100 (O'Kelly et al., 2021).

Figure 2 (Left) Snorkel fitting baffle (top) and airway filter (Kechli et al., 2020)
Figure 3 (Right) Lateral view of modified snorkel-mask (Kechli et al., 2020)

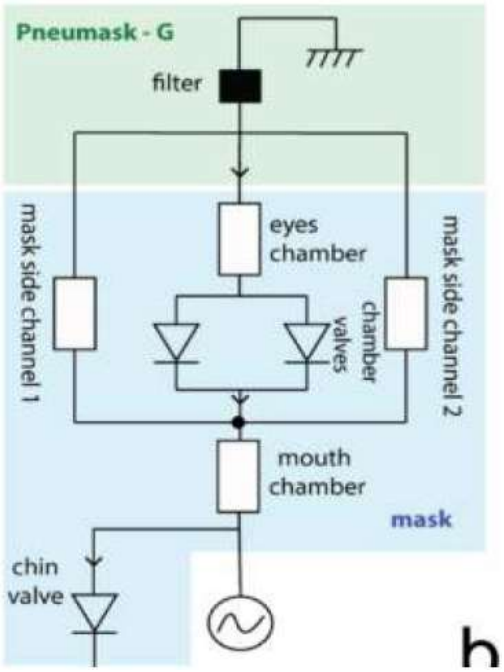

Figure 4 Medical snorkel-mask airway passage (Kroo et al., 2020)

In another study by Nicholson et al. (2020), the fitting test was carried out using OSHA 29CFR1910 and 134 Porta Count 8030 protocols. The test results obtained a fitting factor score that exceeded the pass level. Fittings are an important aspect of ensuring that air circulates through the system properly. A poor-fitting score indicates the number of particles that can enter the mask chamber without passing through the barrier system (O'Kelly et al., 2021). In addition to the design and materials used, the way each individual uses it can also have an effect, so correct use is needed to get maximum accuracy.

In terms of the filtration function, the medical snorkel mask is equipped with a HEPA filter PALL Ultipor 25 which is claimed to have an efficiency rate of 99.99% in filtering particles up to 0.3 microns. This figure is slightly higher than the 95% N95 efficiency rate (O'Kelly et al., 2021). One of the features of the medical snorkel mask is the portable filtration system so that it can be replaced with other filter options. Another option that can be used is the 3M filter variant with one type of 3M type P100 particulate capable of filtering up to an efficiency level of 99.97% (Nicholson, et al., 2020).

Strengths

The advantage of medical snorkel masks is that they serve two important purposes: eye and face protection, and high-quality air filtration to protect against SARS-CoV-2. Medical snorkel masks are claimed to provide an optimal balance between comfort and fit factors (Nicholson et al., 2020). The full-face design will minimize direct contact and contamination from droplets and is easy to sterilize for reuse (Tack et al., 2020). It is quite effective as well in helping to reduce single-use medical waste. The medical snorkel mask is also a practical alternative to replace goggles or face shields.

Another advantage is the effectiveness of filtration by minimizing the potential for filtrate failure. According to Viccini et al. (2020), FFP2-3 masks (medical masks) may lose their filtering function if they are wet due to liquid penetration in the fabric. In medical snorkel masks, this can be avoided because the filtration compartment is not directly facing the mouth which prevents fluid to penetrate the filtration and there are drainage holes provided. The filtrate in the medical snorkel mask can also be easily replaced if it is over the limit.

Weaknesses and solutions

In addition to the various advantages it has, medical snorkel masks also have disadvantages. According to Liu et al. (2020), wearing properly fitted and tightly closed respirator results in the user's voice mumbling and lowering the volume thereby

affecting communication, especially when the breathing valve is tightly closed and the environment is crowded. To help the sound travel through the mask, a microphone can be added to the mask that can be connected via bluetooth. Then, a mobile application was made to convey audio from the bluetooth microphone inside the mask to the speaker outside the mask. Sound can be played on the phone's internal speaker or through a speaker connected to the device's wired headphone port (Kroo et al., 2020).

According to Schmitt et al. (2020), this form of a full-face mask does not allow the use of glasses together with a mask. However, this can be overcome by using contact lenses or contact lenses for users who need glasses. In addition, this weakness can be anticipated by modifying the mask, especially in the visual compartment with the addition of a lens that is fit and following the needs of the user's eye. Another drawback of this mask is the accumulation of carbon dioxide (CO_2). The results of the CO_2 accumulation test showed that the steady-state CO_2 concentration in the mask was around 1-2%, which is generally safe for short-term use and comparable to commercial elastomeric respirators (Caretti and Coyne, 2008; Roberge et al., 2010).

According to Kroo et al. (2020), this mask takes a little time to adapt to breathing to a comfortable level. To clean the mask from CO_2 buildup, deep forced breathing can be done periodically (every 5-10 minutes). In several studies, several types of snorkel masks, such as Scubea & Oceanreef, have had good drainage systems so that when the CO_2 accumulation test was carried out, a minimal increase in tidal CO_2 was obtained during rest and exercise (Germonpre et al., 2020).

A further drawback of medical snorkel masks is the increased work of breathing. This has been described by Kechli et al. (2020) who confirmed that with an airway filter tightly applied to a medical snorkel-mask insert, no increase was seen in an inspiratory or expiratory effort at rest. In addition, wearing this mask and airway filter for 20 minutes at rest and 10 minutes during moderate exercise does not increase respiratory resistance and does not cause hypercapnia or hypoxemia.

Limited vision may also be complained of in the use of medical snorkel masks. This happens because there is a separation between the visual and respiratory compartments that obstructs the view, especially at the bottom. To overcome this, design and material improvements can be made so that the view becomes wider. The silicone material used can be replaced with a material that remains fit and transparent. If the problem persists, mimicking an astronaut's spacesuit helmet is a considerable solution. Another problem would be the fog covering the vision. This can be solved by using anti-fog glass material (Agarwal, et al., 2021).

In addition, because medical snorkel masks are not disposable masks, periodic monitoring and checking of protection rates are required. Proper and adequate sterilization is required after use to prevent the spread of infection. Using isopropyl alcohol or even UV light can be sufficient (Ramos, et al., 2020). For better results, Wang, et al., (2020) propose using pre-programmed automatic spray cleaning and disinfection machine with 2000 mg/L chlorine-containing disinfectant at 70 ℃ for 30 min (Wang, et al., 2020). Another common problem with wearing medical snorkel masks which is also a classic problem with wearing PPE is the discomfort of prolonged use due to excessive sweating. This problem can be minimized by

designing adequate ventilation while maintaining an optimal barrier system.

CONCLUSIONS

The working mechanism of this medical snorkel-mask is the modification of the snorkel mask by adding a filter on the upper air circulation channel, which functions as an air filter from viruses and other pathogens. The level of effectiveness and efficiency of the screening process on medical snorkel masks is considered quite high. However, this is also determined by the type of filter used and the accuracy of its use. This filtration process takes place twice, to filter the incoming and outgoing air so that this process can minimize the occurrence of air contamination. To prevent the mixing of air in and out, this mask is also equipped with a one-way valve on each air channel so that the air flows in the same direction.

By considering the efficiency and safety perspective of each component, financial aspects, and availability of materials, the prospect of use of these masks in Indonesia is theoretically effective to be implemented in the future. Therefore, systematic studies on its uses in Indonesia should be carried out to reduce the risk of possible transmission of viruses and other pathogens between patients and health workers, one of which is when performing actions such as intubation, extubation, and tracheostomy in treating Covid-19 patients. It is hoped that these medical snorkel masks can be a promising innovation to overcome the anxiety of using PPE so that later it can reduce the rate of transmission of Covid-19 and reduce the morbidity and mortality of health workers due to exposure to Covid-19.

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