Review

Utility and Effectiveness of N95 Respirators vs. Surgical masks in Protecting Healthcare Workers from Airborne Pathogens: Narrative Review

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**Abstract:** The COVID-19 pandemic has highlighted the importance of occupational health of healthcare workers (HCWs) worldwide as the virus disproportionately affects employees of healthcare facilities. National debates have focused on the efficacy of N95 respirators in decreasing virus transmission and contagion when compared to cheaper, more readily available surgical masks with higher compliance. This article provides a comparative review of N95 respirators vs. surgical masks utility and effectiveness in protecting health care workers from airborne pathogens. We review the recent literature comparing the efficacy of both types of respiratory protection, discuss contraindications for use, appropriate use and methods to increase efficacy. Evidence based guidelines are proposed to help guide hospitals and healthcare systems on occupational health programs and their distribution of respiratory protection.

**Keywords:** COVID-19; Occupational Health; Healthcare Workers; PPE; respirators

1. Introduction

The COVID-19 pandemic has highlighted the importance of protecting health care workers from infection or transmitting infection in the workplace. One problem in evaluating the efficiency of these protective measures is that adherence rates to infection prevention recommendations among HCWs are inconsistent and vary from 10% to 84% on inpatient respiratory protection studies (MacIntyre et al., 2013). N95 respirators provided mechanical filtration and are considered as positive pressure respirators by the National Institute of Occupational Safety and Health. When compared to surgical masks, N95 respirators have been shown to be more efficient tin preventing exposure to aerosols in laboratory studies (Noti et al., 2012), but when compared with clinical effectiveness studies this superiority is not clear (MacIntyre et al., 2013; MacIntyre et al., 2011; Loeb et al., 2009). The lack of proven clinical effectiveness of N95 versus surgical masks in preventing viral transmission may be due to poor compliance and improper use of N95 respirators among healthcare workers.

Both N95 respirators and surgical masks were highly effective in blocking aerosol viral transmission from a simulated patient (Noti et al., 2012) with N95 respirators being more effective than surgical masks. It remains however inconclusive if N95 respirators are more effective for preventing viral respiratory infections (MacIntyre et al., 2013; MacIntyre et al., 2011; Loeb et al., 2009; MacIntyre et al., 2017).

In a recent published systematic review and meta-analysis it was found that both N95 respirators and surgical masks are consistently effective measures in reducing transmission of SARS-CoV-2 (Chu et al., 2020).

This article provides a comparative review of N95 respirators versus surgical masks utility and effectiveness in protecting health care workers from contagion during the COVID-19 pandemic and discusses appropriate use and designation of respiratory protection.

2. Materials and Methods

Cochrane, PubMed, and Google Scholar databases were searched for English-language studies published from January 2000 through November 2020. PRISMA criteria for systematic review was followed in the selection process *(http://www.prisma-statement.org)*. Only epidemiological studies classified as randomized clinical trials (RCTs), meta-analyses, systematic reviews, and observational studies were included. Databases were queried with the search terms “N95 respirators”, “surgical masks”, “prevention”, “respiratory viral infection”, “health care workers”, “Covid-19”, and “influenza”. We identified a total of 291 articles after removing duplicates between databases .

The abstracts were scanned to assess their appropriateness to be included according to PRISMA criteria (Figure 1). The full text was read for 53 articles found to be eligible based on the inclusion and exclusion criteria summarized in table 1. Thirteen articles are included in the final review based on study design, control for bias and misclassification, relevance to clinical practice and having a comparative analysis between surgical and N95 masks.

**Table 1.** Literature review Inclusion/exclusion criteria.

|  |  |
| --- | --- |
| **Inclusion Criteria** | **Exclusion Criteria** |
| ***Population***: HCWs***Settings***: Inpatient and outpatient healthcare settings worldwide | Editorials, reviews, guidelines, public press articles; theoretical models, conference abstract, opinion and letters to editor |
| ***Intervention***Personal Protective Equipment (PPE): Comparing *N95* respirators vs. Surgical masks / diminishing the risk of respiratory viral infection |  |
| ***Study design*:**Published, peer-reviewed randomized control trials (RCTs), systematic reviews and meta-analysis  |  |
| **Outcome** Respiratory viral Infection –Clinical or laboratory confirmed (SARS2, SARS1, MARS, Influenza) |  |

3. Results

Table 2 summarizes the 13 articles which assess the comparative efficacy of N95 respirators in preventing viral respiratory infections when compared to surgical masks. Most of the studies reviewed concluded there is no significant difference between N95 respirators and surgical masks in preventing laboratory confirmed viral (including coronavirus) respiratory infection (MacIntyre et al., 2013; MacIntyre et al., 2011; Loeb et al., 2009; MacIntyre et al., 2017; Chu et al., 2020; Bartoszko et al., 2020; Wang et al., 2020; Long et al., 2020; Radonovich et al., 2019; Offeddu et al., 2017; Chen et al., 2017; Smith et al., 2016). Some of these studies agree on the superiority of N95 respirators filtering capacity in laboratory settings so this should be reflected in infection control guidelines to ensure the occupational health and safety of HCW (MacIntyre et al., 2013; MacIntyre et al., 2011; MacIntyre et al., 2017; Offeddu et al., 2017; Chen et al., 2017; Smith et al., 2016; Rengasamy et al., 2017). In the case of a highly pathogenic pandemic, N95 respirator use in HCW would likely be a cost-effective intervention (Mukerji et al., 2017).

Figure 1. PRISMA flow diagram of database search results

## Identification

## Eligibility

## Included

## Screening

Additional records identified through other sources
(n = 0)

Records identified through database searching
(n = 411)

**Table 2.** Efficacy of N95 Respirators versus surgical masks preventing viral respiratory infection (SARSCo1-MERS-influenza-SARSCo2).

Full-text articles excluded
(n = 40)

Records excluded
(n = 238)

Records after duplicates removed
(n = 291)

Records screened
(n = 291)

Studies included in qualitative synthesis
(n = 13)

Full-text articles assessed for eligibility
(n = 53)

|  |  |  |  |
| --- | --- | --- | --- |
| **Author-Year** | **Study Population**  | **Study Design** |  **Results** |
| D Loeb et al. (2009) | 446 nurses | Randomized controlled trial | Use of surgical masks when compared to N95 resulted in non-inferior rates of laboratory confirmed influenza. |
| Ch Chu et al. (2020) | 10 adjusted studies (n=2647);29 unadjusted studies (n=10 170)  | Systematic review and Meta-analysis | Use of surgical masks can significantly reduce viral infection; N95 respirators are associated with a larger reduction in risk of infection. |
| Bartoszko et al. (2020)  | 4 RCTs meta-analyzed adjusting for clustering.6, 418 participants | Systematic review and Meta-analysis  |  The use of surgical masks did not increase the risk of laboratory confirmed viral infection compared to N95 respirators. |
| Wang et al. (2020) | 493 participants | Retrospectively collected COVID-19 infection data  |  The use of N95 respirators, together with other hygienic measures like hand washing and disinfection, reduce the risk of COVID-19 infection. |
| Long et al. (2020) | 6 RCTs involving 9, 171 participants  | Systematic review and Meta-analysis | There is no difference in risk of laboratory confirmed influenza between the use of N95 respirators and surgical masks.  |
| Radonovich et al. (2019)  | 2,862 participants |  A Pragmatic cluster RTC | There is no significant difference in the rates of laboratory-confirmed influenza between N95 respirators, compared with surgical masks. |
| Offeddu et al. (2017)  | 6 RCTs and 23 observational studies  | Systematic review and meta-analysis  | N95 respirators may convey greater protection in clinical respiratory infection (CRI) but universal use is likely to be less acceptable due to greater discomfort. |
| MacIntyre et al. (2017) | 3,591participants | 2 Homogeneous RCTs pooled results | N95 respirators are superior to surgical masks in preventing clinical respiratory infection in HCWs.  |
| Chen et al. (2017) | 949 participants wore N95  | A prospective cluster RTC | N95 respirators provided herd protection from respiratory infections.  |
| Mukerji et al. (2017)  | Cost-effectiveness analysis model utilizing efficacy and resource use data | 2 cluster RTCs assessing various mask/respirator strategies  | When facing a highly pathogenic pandemic, HCWs occupational safety is a priority, and the best protection should be given, in this case the use of N95 respirators is considered a cost-effective intervention.  |
| Smith et al. (2016)  | 4,108 participants | 3 Randomized controlled trials (RCTs) 1 cohort study and 2 case–control studies included in meta-analysis.Surrogate exposure studies and laboratory-based experimental evidence | N95 respirators were associated with less filter penetration, less face-seal leakage and less total inward leakage under laboratory experimental conditions but in clinical settings there was no difference between N95 respirators and surgical masks.  |
| MacIntyre et al. (2013)  | 1,669 participants | A cluster RTC | The continuous use of N95 respirators is more effective in preventing clinical respiratory infection than surgical masks. |
| MacIntyre et al. (2011) | 1,441 participants | A cluster RTC | Surgical mask group had two times more risk of presenting either clinical respiratory infection or laboratory-confirmed viral infection compared to N95 group. |

4. Discussion

N95 respirators are so named as they filter at least 95% of particulates greater than 300nm under ideal use. The designation is based on National Institute of Occupational Safety and Health guidelines in the United States. In Europe FFP2 designation filters at least 94% of particulates. There is debate as to whether N95 respirators filter particles at the Nano size, less than 100nm (Bałazy et al., 2006). While these masks are routinely used in industry to filter hazardous dust including silica oxides, there is some evidence that electrostatic forces work to filter particles in the Nano scale such as viruses (Han et al., 2012).

A majority of viruses range 20nm to 250 nm in size; the novel SARS-CoV-2 is 125nm in size (Bar-On et al., 2020; Lee et al., 2008).

N95 respirators, like all negative pressure respirators require increase in breathing effort and increased intrathoracic pressure. As a result, N95 respirators are not appropriate for individuals with moderate to severe obstructive lung disease and congestive heart failure. They are also uncomfortable with prolonged use, decreasing compliance. Efficacy of N95 respirators is dependent upon appropriate fit and use (Coffey et al., 2002; World Health Organization, 2020; Centers for Disease Control and Prevention, 2020). Facial hair, dental implants, improper size and placement can significantly decrease efficacy by more than 70%. Issues of compliance likely explain the lack of improved efficacy of N95 respirators when compared to surgical masks in the literature reviewed.

Fit testing is a process by which proper seal of the respirator is evaluated through either qualitative or quantitative means. Qualitative testing involves administering bitrex or saccharin into a test hood which illicit either a bitter or sweet taste respectively if there is leakage. Quantitative testing is more costly and time intensive as the degree of leakage is measured by a particle counter (Lee et al., 2008; Coffey et al., 2002; Centers for Disease Control and Prevention, 2020). Many hospital occupational health departments have protocols for annual fit testing for employees who are designated as requiring N95 respirators.

A surgical mask is not a respirator and is not intended to filter Nano size particles such as viruses. The primary utility of surgical masks is minimizing the shedding of liquid droplets during surgical procedures. Unlike respirators surgical masks do not increase respiratory workload or intrathoracic pressure and are not contraindicated in individuals with chronic cardiopulmonary disorders. The recommendation for global use of surgical masks among the general population has been a point of contention as the WHO and many national ministries of health have vacillated on recommendations.

Most of the studies reviewed concluded no significant difference between N95 respirators and surgical masks in preventing laboratory confirmed viral (including coronavirus) respiratory infection, however there is also evidence on the superiority of N95 respirators filtering capacity in laboratory settings (MacIntyre et al., 2013; MacIntyre et al., 2011; MacIntyre et al., 2017; Offeddu et al., 2017; Chen et al., 2017; Smith et al., 2016; Rengasamy et al., 2017; Bałazy et al., 2006; Han et al., 2012; Bar-On et al., 2020; Lee et al., 2008). This should be reflected in infection control guidelines to ensure the occupational health and safety of HCWs. Risk of exposure and infection should be assessed based on the role of HCWs on the hospital setting, with N95 respirators reserved for HCWs who are in direct contact with COVID-19 confirmed hospitalized patients and especially those who perform aerosol producing procedures (World Health Organization, 2020; Centers for Disease Control and Prevention, 2020; Greenhalgh et al., 2020).

There is a common misconception that droplets originate solely from coughing or sneezing, and that aerosols are only produced during moments of aerosol-generating procedures such as intubation. Coronaviruses are known to spread by all three methods, airborne inhalation, short range spray and larger fomites (Lei et al., 2018). Influenza can spread through tidal breathing, without any cough or sneeze (Fabian et al., 2008). Small droplets can evaporate into ’droplet nuclei’, remain suspended in air for significant periods of time and could be inhaled transmitted by droplet nuclei (Tellier et al., 2019). Larger droplets are also known to transmit viruses, usually by settling onto surfaces that are touched and transported by hands onto mucosal membranes such as the eyes, nose and mouth (Centers for Disease Control and Prevention, 2020). The characteristic diameter of large droplets produced by sneezing is ~100 mm (Han et al., 2013) while the diameter of droplet nuclei produced by coughing is on the order of ~1 mm (Yang et al., 2007). At present, it is unclear whether surfaces or air are the dominant mode of SARS-CoV-2 transmission, but N95 masks will provide protection against both (Jefferson et al., 2009; Leung et al., 2020).

Sars-CoV-2 can persist in the air for almost 3 hours (Van Doremalen et al., 2020), although it is not still clear how much of this viral load is needed to infect a patient. N95 respirators are capable of filtering just 95% of particles so there is a potential risk load transmission of 5%.

The recommendations derived from the clinical experience obtained at Zhejiang Hospital in China 2020, are that N95 respirators should be used for any contact accompanied by the continuous use of plasma air sterilizers and ultraviolet lamps three times a day for one hour and disinfection of fecal matter and sewage with chlorine containing solutions prior to disposal (Skorzewska, 2020). The goal in transmission prevention is to minimize the viral load in the environment as much as possible.

Further high-quality research is urgently needed for health care workers infection protection measures in this COVID-19 pandemic (Chu et al., 2020; Bartoszko et al., 2020). According to 2007 SARS Commission statement (Campbell, 2006), any reasonable action taken to reduce the occupational risk of health care workers such as the use of N95 respirators, does not need to wait for scientific consensus. In situations such as the current pandemic that involves the safety of health care workers, we should apply the precautionary principle in order to protect the most healthcare workers possible and maintain functioning healthcare systems (Webster, 2007).

We would also like to address four clinically important questions:

1. How effective are N95 respirators in decreasing exposure to viruses?

N95 respirators are more effective in decreasing exposure to viruses than surgical masks due to their higher filtering capacity in laboratory settings (MacIntyre et al., 2013; MacIntyre et al., 2011; MacIntyre et al., 2017; Offeddu et al., 2017; Chen et al., 2017; Smith et al., 2016; Rengasamy et al., 2017; Bałazy et al., 2006; Han et al., 2012; Bar-On et al., 2020; Lee et al., 2008), however there remains controversy in their efficacy on clinical settings where there appears to be no significant difference with surgical masks in preventing laboratory confirmed viral infection due to the need of fit testing, higher discomfort, inadequate and low compliance of use (MacIntyre et al., 2017; Bartoszko et al., 2020; Offeddu et al., 2017; Lee et al., 2008; Jefferson et al., 2009).

2. How effective are surgical masks in decreasing infection transmission?

Surgical masks are very effective because they stop droplets or aerosol from infected individuals to spread while talking, coughing or sneezing acting as a passive barrier, they also reduce fomite transmission preventing infected persons to spread the infection after touching their nose, eyes or mouth (Bischoff et al., 2011).

There is growing evidence of the role of asymptomatic patients in spreading the disease (Chan and Yuen, 2020). We strongly recommend the universal use of surgical masks in public areas based on its greatest importance in decreasing infection transmission of COVID-19 (Chan et al., 2020; Guan et al., 2020).

3. Are N95 respirators more effective than surgical masks in preventing COVID-19 respiratory infection?

According to the published literature reviewed to date there is no significant difference between surgical masks and N95 respirators in decreasing respiratory infection transmission among HCWs in clinical settings. Surgical masks may even be more effective due to higher compliance of use and less hand to face contact.

In this matter we agree with the recommendation of assessing the risk of exposure and infection depending on the role of each HCW, in the clinical setting (World Health Organization, 2020; Centers for Disease Control and Prevention, 2020; Greenhalgh et al., 2020). The decision on when a respirator is required must be based on the HCW’s risk assessment to streamline resource allocation.

Priority should be given to the use of N95 respirators for HCWs who are in direct contact with COVID-19 confirmed hospitalized patients and especially those who perform aerosol producing procedures (Harnish et al., 2016; The Joint Commission, 2014; Cook, 2020) used together with hand hygiene and other recommended PPE: aprons or gowns, goggles or face shields, and gloves (Bischoff et al., 2011).

HCWs must be provided with all the recommended PPE according to WHO technical specifications (World Health Organization, 2020). However, masks and respirators should never be considered as isolated measures and should be combined with other social and environmental measures. It is important to implement an effective training program to ensure proper use of PPE (Centers for Disease Control and Prevention, 2020; Greenhalgh et al., 2020; The Joint Commission, 2014; Cook, 2020; Huh, 2020; Phin, 2020).

Both N95 respirators and surgical masks are effective and have important roles in protecting HCWs. Surgical masks are important for HCWs who fail fit testing, have a medical contraindication, have low risk of transmission, or have compliance issues.

Noncompliance in terms of adjusting the N95 respirators has been found to be 25.7 times per 12 –hour shift (approximately 2 times /hour) Compliance is lower in overweight or obese HCWs (Rebmann et al., 2013). The risk of seal leakage is increased by body movement while performing medical procedures by HCWs (Suen et al., 2017).

Universal use of surgical masks, adequate hand hygiene together with other recommended PPE are very effective infection control measures and should be considered for HCWs in lower risk areas of the hospital or in case of hospital settings with low economic resources or limited supply of N95 respirators (Hopman et al., 2020; Emanuel et al., 2020; Bong et al., 2020).

4. What is the cost-benefit of N95 vs. facemasks.

HCWs should be protected with the best protection available as we are facing a highly contagious viral respiratory infection (between 3.5-20% HCWs reported infected), with a high case fatality rate, caused by a novel virus with a multimodal way of transmission and with still limited proven effective interventions (Ha, 2020).

The COVID-19 pandemic has stretched health systems to a near breaking point globally. Supply chains have been disrupted and there are shortages of critical equipment including PPE. Assessing cost-effectiveness of any intervention is valuable even during normal operation, even more so during a pandemic where resources are scarce. There are significant differences in the cost of surgical masks versus N95 respirators, including personal and equipment costs of fit testing N95 respirators. Previous research has shown N95 usage has an incremental cost of USD $490-$1230 to prevent one clinical respiratory illness (Mukerji et al., 2017). Considering the relatively high mortality of the COVID-19 and significant strain on the health care system, the additional cost of N95 respirator for at risk HCWs is cost-effective (Mukerji et al., 2017). Extended use of N95 respirators may be considered if guidelines are adhered (Farrokhian et al., 2020; Rebmann et al., 2009). The efficacy of both N95 and facemasks are greatly enhanced when a safe inter-personal distance between cases is maintained (Setti et al., 2020) .

5. Conclusions

In conclusion, most of the recent systematic reviews and meta-analysis concluded that there is no significant difference between N95 respirators and surgical masks in preventing laboratory confirmed viral respiratory infection including coronavirus. And while there is evidence on the superiority of N95 respirators filtering capacity in laboratory settings, clinical efficacy is limited by compliance issues. Both N95 and surgical masks play a crucial role in mitigating public health impact from the COVID-19 pandemic and protecting HCWs. Assessing appropriateness (contraindications, fit testing) and necessity (risk of exposure and infection) of N95 use among HCW must be determined on a case-by-case bases. Priority should be given to the use of N95 respirators for HCW who are in direct contact with COVID-19 confirmed hospitalized patients and especially those who perform aerosol-generating procedures.

The COVID-19 pandemic is a major challenge for the international scientific community. It has shown us our vulnerability and weakness in dealing with a novel highly contagious respiratory viral infection and has reminded us that communicable diseases should never be underestimated. We must be prepared to deal with them with sufficient resources to protect HCWs, our most valuable resource in managing the current pandemic (Kolifarhood et al., 2020).

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