Quantifying exposure risk: Surgical masks and respirators

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Background: The interaction between the source of respiratory infectious aerosols and the receiver has not been investigated. Using a bench model, we measured the effects of filtration and deflection achieved with surgical masks and N95 respirators.

Methods: We constructed a chamber designed to produce radiolabeled wet aerosols simulating contaminated particles exhaled during tidal breathing (source). Particles within the chamber were exposed to either 6 or 0 air exchanges/hr. Aerosols were defined by cascade impaction. Source aerosols were exhaled via a ventilated mannequin head suitable for mask protection. A similar ventilated head within the chamber assessed recipient exposure (receiver). A filter within the receiver quantified exposure. Two types of masks, an N95 respirator and surgical mask, were tested. Data were presented as percent of nebulized particles on the receiver filter (exposure) and simulated workplace protection factor (sWPF).

Results: In the presence of chamber air exchange, applying a mask on the source (primarily deflection) resulted in significant reduction in exposure to the receiver (sWPF170-320). Masks on receiver (filtration) did not significantly reduce exposure from that of no masks (sWPF1.37-2.21), except with a Vaseline seal (sWPF118). With 0 air exchanges/hr, only Vaseline seal was effective in reducing exposure (sWPF 16-101).

Conclusion: In a ventilated space, deflection of exhaled particles with a mask worn at the source achieved far greater levels of protection than any mask on the receiver. Mask filtration at source or receiver did not play a significant role in reducing exposure.

Key Words: Aerosol; tidal breathing; infection control; workplace protection factors.

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A recently published report suggested that the use of standard ear loop procedural (surgical) masks may reduce transmission of influenza-like illness.[1] To protect health care workers (HCWs) the Centers for Disease Control and Prevention (CDC) recommends surgical masks for seasonal influenza but N95 respirators for the 2009 novel H1N1 virus.[2-5] The former is based on the assumption that transmission is via direct contact or large, airborne droplets[6] (>5 μm), the latter by aerosolized particles (<5 μm) that would be better intercepted by the greater filtration capability of N95 respirators.[7] However, there is no firm understanding of the various potential transmission mechanisms of influenza.[3,4] The current literature focuses on inhalational barrier protection (filtration) worn by a HCW.[8-11] Surgical masks were originally intended to prevent contamination of the surgical field by infectious organisms emitted by surgeons and other operating room personnel, yet these masks are commonly compared with N95 respirators, which were designed specifically as inhalational protection devices. Surgical masks worn by potentially infectious individuals may be efficacious in containing exhaled aerosols offering protection to those around them.[5,12,13] However, this effect has not been quantified in terms of relative protection utilizing current National Institute of Occupational Safety and Health (NIOSH) workplace protection factors (WPF).

We designed an in vitro bench model to assess the effect of surgical mask and respirator interaction on different mechanisms of protection from potential exposure. Figure 1 illustrates the principles of the model emphasizing each measurable parameter including the following: the breathing patterns of the presumed infected "source" and uninfected "receiver," the aerosols produced at the source, the effects of the chamber on aerosol dilution and particle modification, the effects

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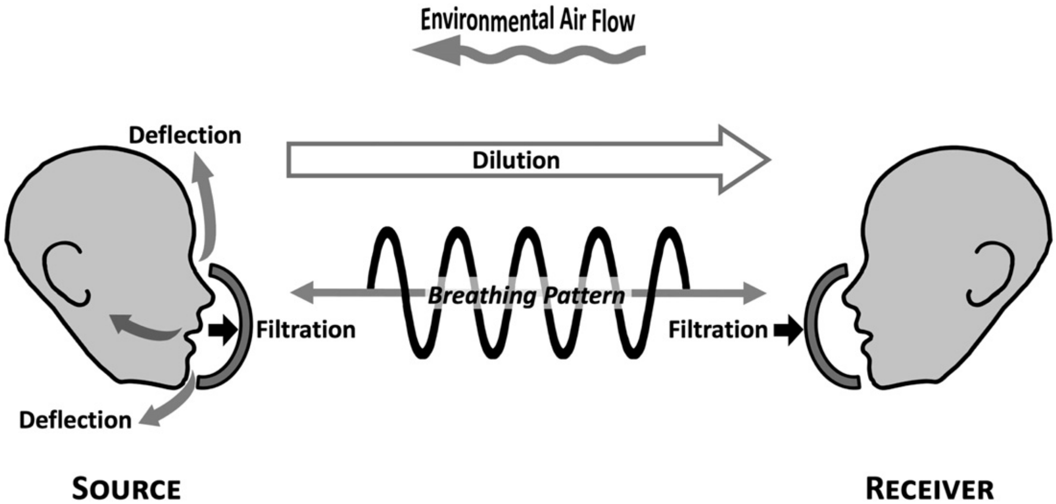

Fig 1. Model of source/receiver/environment interaction. Parameters than can be set or measured are shown.

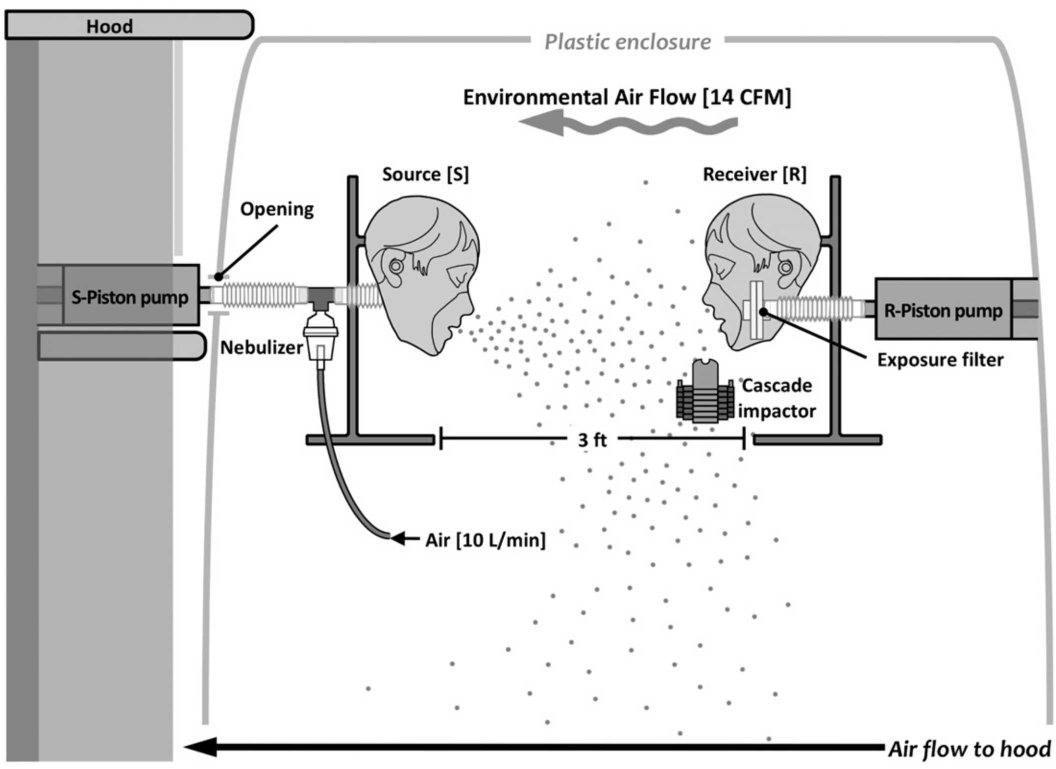

Fig 2. Schematic representation of experimental setup. Breathing pattern of both source and receiver; tidal volume 500 mL, rate 15 breaths/min, and duty cycle 0.5. Environmental flow in chamber (ft^3/min or CFM) was regulated via opening between hood and chamber. In separate experiments, cascade impactor measured particle distribution of aerosol inhaled by receiver. Exposure defined by radioactivity captured on exposure filter in receiver.

of filtration using filters on source and receiver, particle deflection by mask and chamber air exchange. We examined multiple potential mechanisms of protection that masks and/or respirators may offer, including dilution, deflection, and filtration when worn either at the source (patient) or the receiver (HCW or others). The goal was to provide a scientific basis for designing future clinical studies.