SCHLIEREN AND LASER FLOW VISUALIZATION OF FILTRATION AND LEAKAGE OF DIFFERENT FACEMASKS

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Abstract

Background and objective:
Due to the differing fibre densities and thicknesses of varying masks, some masks are more effective in blocking respiratory droplets than others. Mask protective efficiency depends not only on filtration efficiency, but also on the leakage fraction. To determine the effectiveness of different masks in preventing the transmission of COVID-19, Schlieren Optical Imaging (SOI) and laser sheet systems will be used to visualize the airflow during respiration. The objective of this study was to visualize the expiratory airflows from facemasks.
Methods:

(1) develop an optimal Schlieren system to visualize facemask flows.
(2) develop a laser system and visualize the facemask flows.
(3) use vapor to simulate aerosol transmission between two persons.

Summary of results:

(1) Surgical mask and KN95 reduce the exhaled flow velocity from 2~4 m/s (with no facemask) to around 0.1 m/s, thus decrease the transmission of virus-laden respiratory droplets. However, they have flow resistance.
(2) Bandana or n-gaiter has low filtration efficiency and high leakage fractions, thus provides low protection efficiency.
(3) Respiratory droplets mainly deposit around nose/mouth. Frequent touching these regions will increase transmission.
(4) (4) Even KN95 and surgical mask can have 50% leakage from the gaps around the nose.

Figures

Considering the different physical properties of the respiratory airflow and droplets, four visualization methods have been developed. The Schlieren optical system will capture the in vivo expiration flows and is good at detecting facemask leakage (Fig. 1a). The laser optical system can vividly capture the details of the airflow patterns but has been only used for in vitro testing for safety reasons (Fig. 1b). The vapor-Sargel system mimicked the inter-personal transmission of respiratory droplets both qualitatively and quantitatively (Fig. 1c). The infrared thermal camera can capture the transient inhalation and exhalation, as well as the flow leakage, within breathing cycles (Fig. 1d). To consider the age effects on inter-personal transmission, 3D-printed head models of different ages were prepared.

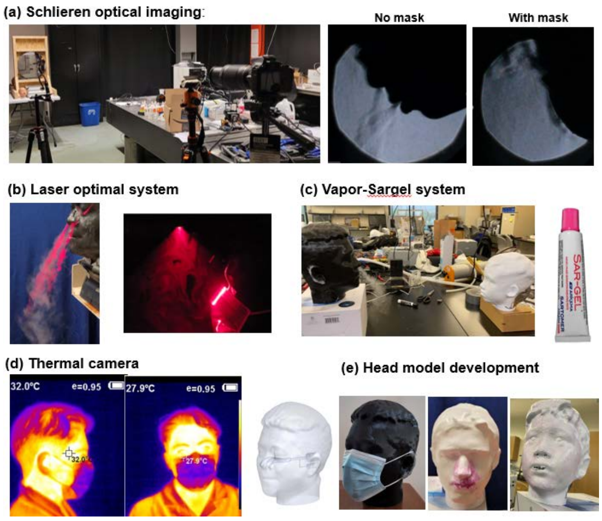

Figure 1: Visualization methods: (a) Schlieren optimal system (SOI), (b) laser optical system, (c) vapor-Sargel system, (d) thermal camera, and (e) head models of varying ages.

Schlieren optical imaging of facemask under varying activity conditions (in vivo) is shown in Figs. 2a-c for surgical, KN95, and N-gaitor, respectively.

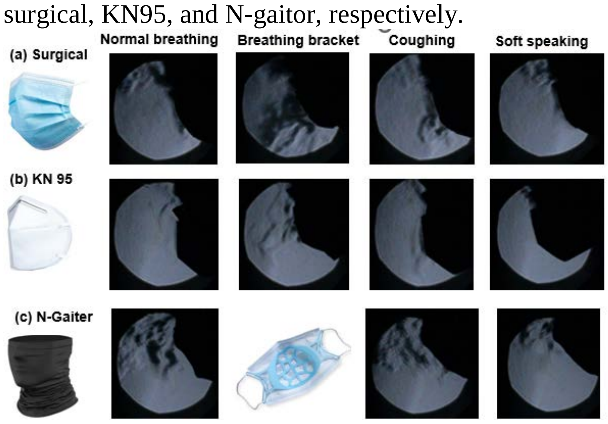

Figure 2: expiratory flows through facemasks.

References

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