CHEST

Exhaled Air Dispersion During Noninvasive Ventilation via Helmets and a Total Facemask

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BACKGROUND: Noninvasive ventilation (NIV) via helmet or total facemask is an option for managing patients with respiratory infections in respiratory failure. However, the risk of nosocomial infection is unknown.

METHODS: We examined exhaled air dispersion during NIV using a human patient simulator reclined at 45° in a negative pressure room with 12 air changes/h by two different helmets via a ventilator and a total facemask via a bilevel positive airway pressure device. Exhaled air was marked by intrapulmonary smoke particles, illuminated by laser light sheet, and captured by a video camera for data analysis. Significant exposure was defined as where there was ≥ 20% of normalized smoke concentration.

RESULTS: During NIV via a helmet with the simulator programmed in mild lung injury, exhaled air leaked through the neck-helmet interface with a radial distance of 150 to 230 mm when inspiratory positive airway pressure was increased from 12 to 20 cm H_2O, respectively, while keeping the expiratory pressure at 10 cm H_2O. During NIV via a helmet with air cushion around the neck, there was negligible air leakage. During NIV via a total facemask for mild lung injury, air leaked through the exhalation port to 618 and 812 mm when inspiratory pressure was increased from 10 to 18 cm H_2O, respectively, with the expiratory pressure at 5 cm H_2O.

CONCLUSIONS: A helmet with a good seal around the neck is needed to prevent nosocomial infection during NIV for patients with respiratory infections.

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ABBREVIATIONS: ACH = air changes per hour; A(H1N1) = pandemic 2009 influenza A(H1N1); EPAP = expiratory positive airway pressure; HCW = health-care worker; HPS = human patient simulator; IPAP = inspiratory positive airway pressure; NIV = noninvasive ventilation; SARI = severe acute respiratory infection; SARS = severe acute respiratory syndrome

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Respiratory failure is a major complication in patients hospitalized with severe acute respiratory infections (SARIs), such as severe acute respiratory syndrome (SARS),[1,2] pandemic 2009 influenza A(H1N1) (A[H1N1]),[3] avian influenza (A[H5N1] or A[H7N9]),[4,5] and the Middle East respiratory syndrome.[6,7] Patients may progress rapidly to ARDS and multiorgan failure, requiring intensive care support.[1-8] Noninvasive ventilation (NIV) may play a supportive role in patients with early ARDS or acute lung injury due to SARI as a bridge to invasive mechanical ventilation.[8-10] However, a systematic review has shown that mask ventilation, tracheal intubation, tracheotomy, and NIV may increase the risk of nosocomial transmission of respiratory infections to health-care workers (HCWs).[11]

Following the outbreak of SARS and emergence of the A(H1N1) infection, it has been recommended that when NIV is required for patients with acute hypoxemic respiratory failure due to SARI, infection control measures such as the use of helmets or full facemasks, double circuit tubes, and addition of viral-bacterial filters be considered.[10,12] However, whether these infection control measures are effective in minimizing exhaled air leakage has not been objectively evaluated. This study aimed to examine the dispersion of exhaled air during application of NIV via helmets and total facemask. Knowledge about the extent of exhaled air leakage from different masks will facilitate the development of preventive measures to reduce the risk of nosocomial transmission during application of NIV to high-risk patients hospitalized with SARI.

Materials and Methods

We examined the extent of exhaled air dispersion during application of NIV on a high-fidelity human patient simulator (HPS) (HPS 6.1; CAE Healthcare, Inc) via two different helmets (PN530L; Sea-Long Medical Systems Inc, and StarMed CaStar R; Intersurgical Ltd) using a SERVO-i ventilator (MAQUET) with double-limb circuit and filters. In addition, we studied the deliberate leakage from the exhalation port of a total facemask (Koninklijke Philips N.V.) during NIV via a bilevel positive airway pressure device and a single-limb circuit firmly attached to the HPS (Fig 1).

The experiments were conducted in a negative pressure room, with 12 air changes/h (ACH) (Fig 2). The experimental design and method of data analysis have been described in detail in our previous studies on exhaled air dispersion related to the application of NIV,[12,13] oxygen masks,[14,15] jet nebulizer,[16] and mask ventilation.[17]

NIV and Lung Model

The HPS represented a 70-kg adult man sitting on a 45°-inclined hospital bed. It was programmed to breathe spontaneously to mimic different degrees of lung injury (Table 1).[12-19] The HPS contains a realistic airway and a lung model that undergoes gas exchange by removing oxygen and adding CO_2 to the system simultaneously. The lung compliance and airway resistance respond in a realistic manner to relevant respiratory challenges. In addition, the HPS produces an airflow pattern that is close to the in vivo situation and has been applied in previous studies to simulate human respiration.[20-23]

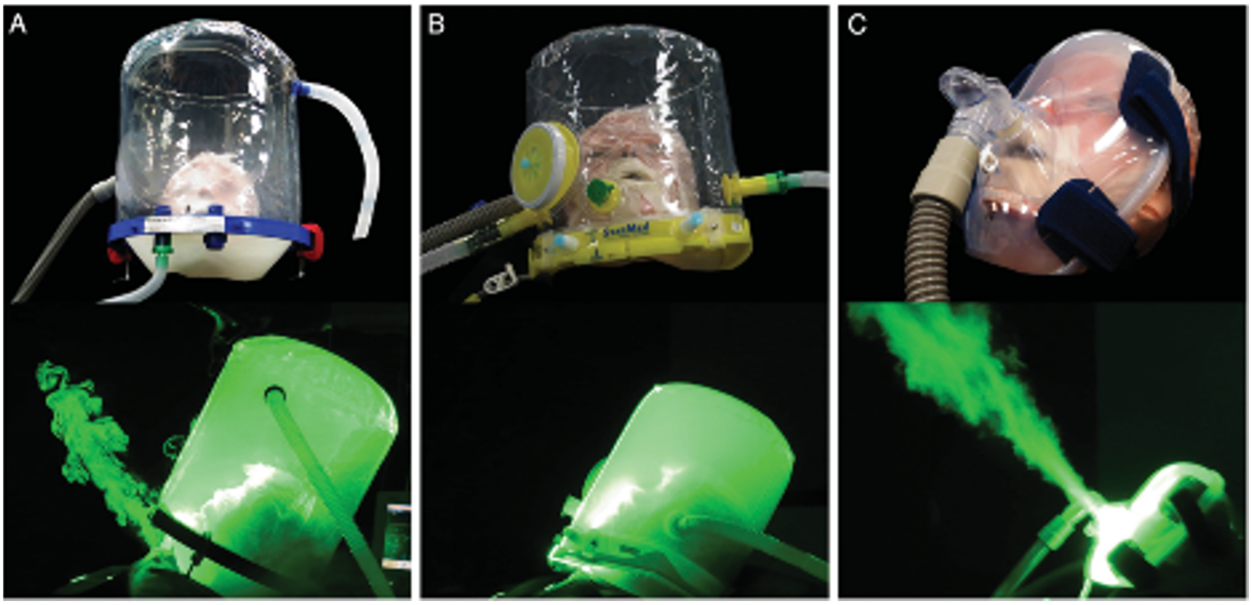

Figure 1 – *A-C, Application of noninvasive ventilation via the Sea-Long helmet (A), StarMed CaStar R helmet (B), and the Respironics total face mask (C) on the human patient simulator (HPS). The HPS represented a 70-kg adult man sitting on a 45°-inclined hospital bed and was programmed to mimic normal breathing, mild lung injury, and severe lung injury. Exhaled air, marked by the smoke particles, is illuminated by the laser light-sheet, with dispersion through the neck interface of the Sea-Long helmet (A) and through the exhalation port of the total face mask attached to the HPS (C). No significant leakage was noted with the StarMed CaStar R helmet.*