The effect of different flow settings on lung impedance using two new HFNC devices: A randomized crossover study on healthy volunteers

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Abstract

Background: High-flow nasal cannula (HFNC) is a device that can reduce the work of breathing (WOB) and improve oxygenation by providing a flow that matches or exceeds patient's peak inspiratory flow during tidal breathing. Despite its widespread use, there remains a lack of consensus regarding the optimal flow settings. Two new HFNC devices that can provide information regarding patient's peak tidal inspiratory flow breath by breath are recently available, which might help guide set and titrate the flow settings. This study aims to investigate the effects of different flow settings on lung impedance in a cohort of healthy volunteers by using the two new HFNC devices.

Methods: This prospective, randomized crossover trial will enroll adult healthy volunteers. Initially, the subject's peak inspiratory flow will be measured using a mask connected with a respiratory monitor. Subsequently, the volunteers will undergo HFNC treatment at different flow settings while their peak inspiratory flow will be continuously monitored. The primary outcome of this study is the lung aeration with different flow settings. Secondary outcomes include the lung aeration with different devices, subject's comfort at different flow settings, and the correlation between the subject's peak inspiratory flow measured by HFNC and by a mask connected with a respiratory monitor.

Results: N/A

Conclusion: N/A

Introduction

High-flow nasal cannula (HFNC) is a widely used medical device.[1] It can deliver flows up to 60-100 liter per minute (LPM) and maintain a consistent fraction of inspired oxygen once the set flow exceeds the patient's tidal inspiratory flow (PTIF).[2] HFNC has demonstrated effectiveness in reducing the risk of intubation in patients with hypoxemic respiratory failure, and can improve ventilation in patients with chronic obstructive pulmonary disease.[3-5] These effects can be attributed to the many benefits offered by the device, including improving ventilation/prefusion matching, reducing the work of breathing, and washing out the dead space of the upper airway.[4-7] Furthermore, when the flow exceeds the PTIF, a positive end-expiratory pressure (PEEP) effect is observed.[6,7] This PEEP effect can be estimated by measuring the end-expiratory lung impedance (EELI), which is reported to be correlated with HFNC flows.[8,9] Despite recommendations that the set flow should match or exceed the PTIF, continuous measurement of PTIF, especially during HFNC treatment, remains challenging, and there is no consensus on optimal flow settings.[10,11] Therefore, a continuous PTIF monitoring could serve as an objective reference for practitioners when determining the initial flow and flow titration for different patients and under different conditions.

Two new HFNC devices, the *OmniOx HFT750 (MEK, Paju-si, South Korea)* and the *Airvo3 (Fisher & Paykel Healthcare Ltd, Auckland, New Zealand),* could potentially provide the solution. The *HFT750* can continuously measure PTIF during therapy, while *Airvo 3* provides a continuous waveform reading of the targeted flow to assess if it meets patient's demand. However, the accuracy and effectiveness of these devices remain unknown. Thus, in our study, we will measure the participants' PTIF via a mask prior to applying the HFNC and compare the flows with those displayed by the HFNC devices during treatment, particularly at different flow settings. We will also measure the lung aeration of different flows using the two devices. Our aim is to investigate the effects of different flows on the homogeneity of lung aeration. Our hypothesis is that as flow setting increases, lung aeration (EELI) will also increase.

Methods

Study Design: Randomized crossover trial

Inclusion criteria: Healthy volunteers between 21-65 years old

Setting: Rush University

Exclusion criteria:

1- Chronic pulmonary diseases, including COPD, interstitial lung disease, cystic fibrosis, etc.

2- Uncontrolled asthma;

3- Pregnancy

4- Subjects who have cold/flu symptoms (sore throat, runny nose, fever, chills, coughing)

5- Nose abnormalities that can affect the functionality of the nasal prongs

Sample size: 26 subjects

This study is a single group comparison study designed to compare the change of EELI with different flow settings during HFNC treatment. In the study by Plotnikow et al that compared HFNC flows of 30 vs 50 L/min, they reported that mean changes of EELI from baseline were 1.12 (0.8, 2.01) at 30 L/min and 1.44 (1.05, 2.16) at 50 L/min. We use this result to calculate the sample size, with confidence level (1 – α) of 95% and power (1 – ß) of 80%, the sample size is calculated to be 26.

Plotnikow GA, Thille AW, Vasquez DN, et al. Effects of High-Flow Nasal Cannula on End-Expiratory Lung Impedance in Semi-Seated Healthy Subjects. Respir Care. 2018;63(8):1016-1023.

Study Procedure:

1- Study will be advertised at Rush University through a poster in a public place

2- Interested participants can contact the study investigator (Omar) through email or phone call which will be provided in the advertisement

3- Interested participants will be assessed for eligibility. If eligible, the study investigator will explain the whole study procedure and the benefits/harms to them in a private room, questions will be answered. Next, participants will be given a minimum of 30 mins to consider participating in the study. Consent will be obtained.

4- At the beginning, an electronic impedance tomography belt will be placed around the torso of the subjects according to their chest size. The participants will rest in a bed with head elevated at 30 degree.

5- Baseline measurement over 5 minutes of respiratory rate, tidal volume and PTIF will be obtained using a respiratory monitor (NICO2, Respironics, Murrysville, PA, USA) through a mask. Then the subject will be coached to breathe normally with room air for 20 mins, at the end, they will be questioned about their comfort level using a visual numerical scale ranging between 0 (extreme discomfort) and 10 (very comfortable).

6- HFNC devices *(~~HFT700~~ HFT750 and Airvo 3)* will be applied, three different flows will be utilized at a random sequence: 20, 40, and 60 L/min. Each flow will be utilized for 20 mins. There is a 5 min break between flows. HFNC will be removed during the break.

7- Between flow settings, PTIF will be measured via the mask and respiratory monitor

8- PTIF (measured by the ~~HFT700~~HFT750) or targeted flow waveform (using Airvo 3), EELI, and respiratory rate will be monitored continuously through the procedure, and comfort level will be assessed at the end of each flow setting

9- The whole procedure is expected to last 3-4 hours

Withdraw criteria:

1- Participant decides to withdraw

2- Participant experiencing adverse events such as pain, coughing, or discomfort.

Data Collection:

All the following data will be collected from the participant and/or during the study.

Demographic variables: Age, sex, and ethnicity

Anthropometric variables: Height, weight

Study variables: Baseline PTIF, respiratory rate and tidal volume via NICO2 (Respironics, Murrysville, PA, USA). Continuous monitoring of PTIF, and respiratory rate during 3 different flow settings via two HFNC devices. Comfort level reported by participants using a visual numerical scale ranging between 0 (extreme discomfort) and 10 (very comfortable) at the end of each flow setting. Quantifying aeration homogeneity using electronic impedance tomography device by assessing EELI, regions of interest (ROI1, ROI2, ROI3, ROI4), and center of ventilation (CoV) during the 3 different flow settings.

Outcomes

- Lung aeration, EELI, respiratory rate, and comfortable level compared at baseline (without HFNC device) with 3 different flow settings
- Lung aeration, EELI, respiratory rate, and comfortable level between two HFNC devices (Airvo 3 vs HFT75~~0~~0)
- PTIFs measured by the mask with respiratory monitor and by the HFT75~~0~~0 device during the HFNC treatment at three flow settings.
- PTIFs measured by the mask with respiratory monitor and PTIF waveform monitored by the Airvo 3 device during the HFNC treatment at three flow settings.

Data Analysis

Kolmogorov-Smirnov will be used to test the normality of distribution for continuous variables. Based on the distribution of the variables, continuous variables (respiratory rate, PTIF and comfort level) will be reported as mean and standard deviation (SD) or median and Inter-Quartile Range (IQR). Friedman or Repeated Measures ANOVA analysis will be used to compare the differences of continuous variables between baseline and 3 flow settings with each HFNC device. Mann-Whitney or independent t test will be used to compare the differences of continuous variables between two devices. Spearman's Rho or Pearson Correlation statistical test will be used to assess the correlation between PTIF measured via mask (NICO2) with PTIF measured by the HFT750 device. A *p*-value of < 0.05 will be considered statistically significant. Data analysis will be conducted with SPSS software (SPSS 26.0; Chicago, IL).

Compensation

Participants will be compensated $25 gift card for participation.

Confidentiality and Special Precautions

The data collected for this clinical study will be obtained from the participant or directly collected during the study procedures which then will be entered to REDCap. All data collected will be assigned a subject ID number. Only de-identified data will be downloaded from REDCap for data analysis. Access to the REDCap data is managed by Rush login IDs and access to this project REDCap (and their data) will be limited to the study investigators. Rush's REDCap system relies upon the institution's identity and access management infrastructure. The password complexity, history and expiration standards are implemented at the institutional level.

References:

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