Student Research Project Proposal

Title:

Carbon Dioxide (CO_2) Clearance from various face masks in Normal Volunteers at various level of Expiratory Positive Airway Pressure (EPAP) when Using a Non-Invasive Positive Pressure Ventilation (NIPPV)

Investigators:

Mentor:
DAVID VINES, MHS, RRT, FAARC, FCCP
Graduate Student:
Ahmed Al Hussain, Respiratory Care Department, Rush University.

Study aim:

Determine the EPAP (baseline pressure) required to effectively wash out CO2 for current available masks, and assess perceived level of comfort with each mask with using noninvasive ventilator.

1- Abstract:

Background: Noninvasive positive pressure ventilation (NIPPV) can be delivered via single limb circuit or double limb circuit ventilators. There are many advantages to NPPV. However, a reasonable number of questions remain unanswered, such as mask impact on carbon dioxide (CO2) clearance based on EPAP level.

Objective: Determine the EPAP (baseline pressure) required to effectively wash out CO2 for each mask, and assess perceived level of comfort with each mask with ICU ventilator.

Method: This study will be a randomized crossover trial that will be conducted at Rush University. The study will be conducted with 20 healthy volunteers who will be placed on ICU ventilator operating in the NIPPV mode. All subjects will perform 15 minutes of breathing on NIPPV on each mask of the 4 different masks (2 oronasal and 2 full face masks) that are randomly selected. Breathing through each mask will be followed by a 5-minute wash out period between masks. End tidal Carbon Dioxide (EtCO2) will be sampled nasal/oral. Different levels of EPAP will be set and CO2 clearance will be monitored. Additionally, subjective mask comfort will be assessed via visual analog scale (VAS) with 1 referring to least comfortable and 5 being the most comfortable.

2- Introduction

Noninvasive positive pressure ventilation (NIPPV) is a form of ventilatory support for spontaneously breathing patients without the need of an artificial airway.[1] NIPPV is recommended for patients with chronic obstructive pulmonary disease (COPD) exacerbation as well as cardiogenic pulmonary edema.[2] The use of NIPPV has reduced the need for intubation and improved mortality.[2] Some studies have demonstrated a decrease in mortality rate in individuals with acute hypoxemic respiratory failure and immunosuppression with the use of NIPPV.[2] Issues that exist with NIPPV is patient compliance or tolerance.[3] NIPPV failure rates can exceed 40%. Mask intolerance remains a major hindrance to NIPPV success.[3,4]

NIPPV uses external interfaces such as nasal mask, facial mask, mouthpiece, or helmet.[1] Noninvasive ventilation (NIPPV) can be delivered by a dedicated NIPPV ventilator which utilizes a single limb circuit requiring an expiratory port to allow for carbon dioxide clearance. This NIPPV ventilator has the ability to adjust for leak and continue to function properly without the mask fitting tightly to the face.[3,4] NIPPV can also be delivered by ICU ventilators which utilize a dual limb circuit and these circuits usually have no leak to properly function. NIPPV interface fitting is another key factor, however, to minimize leak the interface may be over tighten and cause patients discomfort. Patients may complain of NIPPV due to multiple factors, it can be facial discomfort, massive air leak or pressure sores.[5] It has reported that oronasal mask to perform worse with pain at nose bridge in comparison to total face mask.[6] While cheeks' pain was more prevalent in the oronasal mask in comparison to total face mask[7], oronasal dryness and claustrophobic were reported higher with total face mask.[6] It is fair to state that success of NIPPV is dependent on many factors, one of them is mask characteristics.[8] These issues may

decrease patient tolerance of NIPPV.[5] A properly fit mask may increase patient compliance. Moreover, health care providers (HCPs) must have an excellent understanding of NIPPV and the skills to execute the task successfully.[5] However, a concern remains that a single limb circuit with NIPPV ventilators may cause carbon dioxide (CO_2) rebreathing.[9] This CO2 rebreathing can lead to NIPPV failure.

Samolski et al, studied the CO2 rebreathing while using a portable ventilator which uses a single limb circuit. They studied the effect of expiratory port location, different sites of the port (i.e. in the mask, before the mask), and the addition of dead space between the circuit and mask on CO2 rebreathing. They found no CO2 rebreathing, and baseline pressure as low as 4 cm H2O was effective in preventing CO2 rebreathing.[9] However, this study has limitations. First, they used three different nasal masks and 2 different facial masks. Currently there are newer masks available that need testing. Last, they measured fraction of inspired CO2 (FiCO2) via a sampling line located in the mask.[9] The site of sampling can significantly affect the accuracy of end tidal CO2 (EtCO2) measurement. Sampling line at the oral/nasal site may be the most reliable sampling site for EtCO2 and determining rebreathing of exhaled gas.

NIPPV interface choice is crucial to achieve a good clinical outcome with the use of NIPPV. Common interfaces are nasal mask which covers the nose only, facial mask known as oronasal mask which covers the nose and mouth. Total face mask and helmet are gaining popularity. Generally, nasal mask is better tolerated, while oronasal mask is more effective for improving gas exchange. The perfect mask should be lightweight, comfortable, easy to apply, transparent in color, latex-free, have small internal volume and low airflow resistance.[1]

The total face mask which covers the entire face was designed with the aim of enhancing patient tolerance. Newer generation of NIPPV full face masks are available on the market (e.g. PerforMax) which also covers the eyes, nose, and mouth. The mask also, has advantages by minimizing gas leakage. Furthermore, due to its shape, it helps to minimize pressure sores on the face as there is no contact with the nose bridge. On the other hand, the mask has disadvantages such as adding a large dead space, which varies from mask to mask based on different manufacturers. Unlike the larger older generation, this mask comes without the two orifices for CO2 washout.[3,6] To accommodate both types of ventilators (NIPPV and ICU ventilators) this mask comes with two options of an elbow, a standard elbow for use with double circuit ICU ventilators or an entrainment elbow for NIPPV ventilators.[3] It is worth mentioning that the total face mask costs more than the nasal mask or oronasal mask.[10] Despite total face mask's large internal volume, the mask doesn't affect patients' gas exchange during short term of NIPPV using ICU ventilator.[10]

NIPPV masks were developed with an intentional leak to remove CO_2 from the interface.[8] A comparison of three different masks (mask A, mask B, mask C) on healthy volunteers to investigate CO_2 wash out hypothesized that in NIPPV masks with lower rates of intentional leaks, CO_2 rebreathing might occur.[8] Transcutaneous capnography ($PtcCO_2$) was measured. IPAP level of 14 cm H2O, EPAP of 4 cm H2O was applied to all masks. Each subject was placed on NIPPV, and tried all three masks consecutively. Each mask was tested for 10 minutes followed by 5 minutes break in between masks. They found no differences in $PtcCO_2$ between masks.[8] Despite accuracy of $PtcCO_2$ measurement, this study has some limitations. It did not assess CO_2 clearance at the mask

via $EtCO_2$. Masks B & C both had higher rate of total leaks due to higher rate of unintentional leaks which may improved CO_2 wash out, hence, led to no differences in $PtcCO_2$.[8] Another study compared total face mask against oronasal mask impact on gas exchange ($PvCO_2$) favors total face mask in the first 6 hours and during the acute phase of respiratory failure using NIPPV.[7] Both Medrinal and Sadeghi assessed gas exchange not masks' CO_2 clearance. Since the intentional leak impacts CO_2 clearance, and the intentional leak level depends on the level of pressure.[8] The previous studies didn't study different level of EPAP (baseline pressure). One level of EPAP pressure of 4 cm H2O was used in Medrinal study based on Samolski's finding.[8] While in Sadeghi's study, IPAP started at 10 cm H2O and EPAP started at 4 cm H2O. IPAP and EPAP were increased gradually based on subjects' need, therefore it lacked consistency in EPAP level.[9]

ICU ventilators using double limb circuit is an alternative to deliver NIPPV, however, researches on minimum baseline pressure required to prevent CO2 rebreathing is not clear as well. In a study that compared 3 types of masks (2 ONM and 1 FFM) to helmet in acute hypercapnia respiratory failure. NIPPV in both group improved arterial blood gases. ICU ventilators settings in masks group used positive end expiratory pressure (PEEP) referring to baseline pressure that ranged from 3 – 5 cm H2O (mean 4.26 ± 1.92); and inspiratory pressure adjusted to achieve tidal volume of 6-8 ml/kg (16.37 ± 4.19). On the other hand, settings for helmet groups were ~ 30%.[11]

The answer regarding effective EPAP level to wash out CO_2 remains uncertain. The purpose of this study is to compare the efficacy of CO_2 clearance between different NIPPV interfaces (oronasal and full face masks) when using double limb circuit ICU

ventilator at lower levels of EPAP. The aim of this study is to determine the EPAP (baseline pressure) required to effectively wash out CO_2 for each mask and assess perceived level of comfort with each mask.

3- **Methods**:

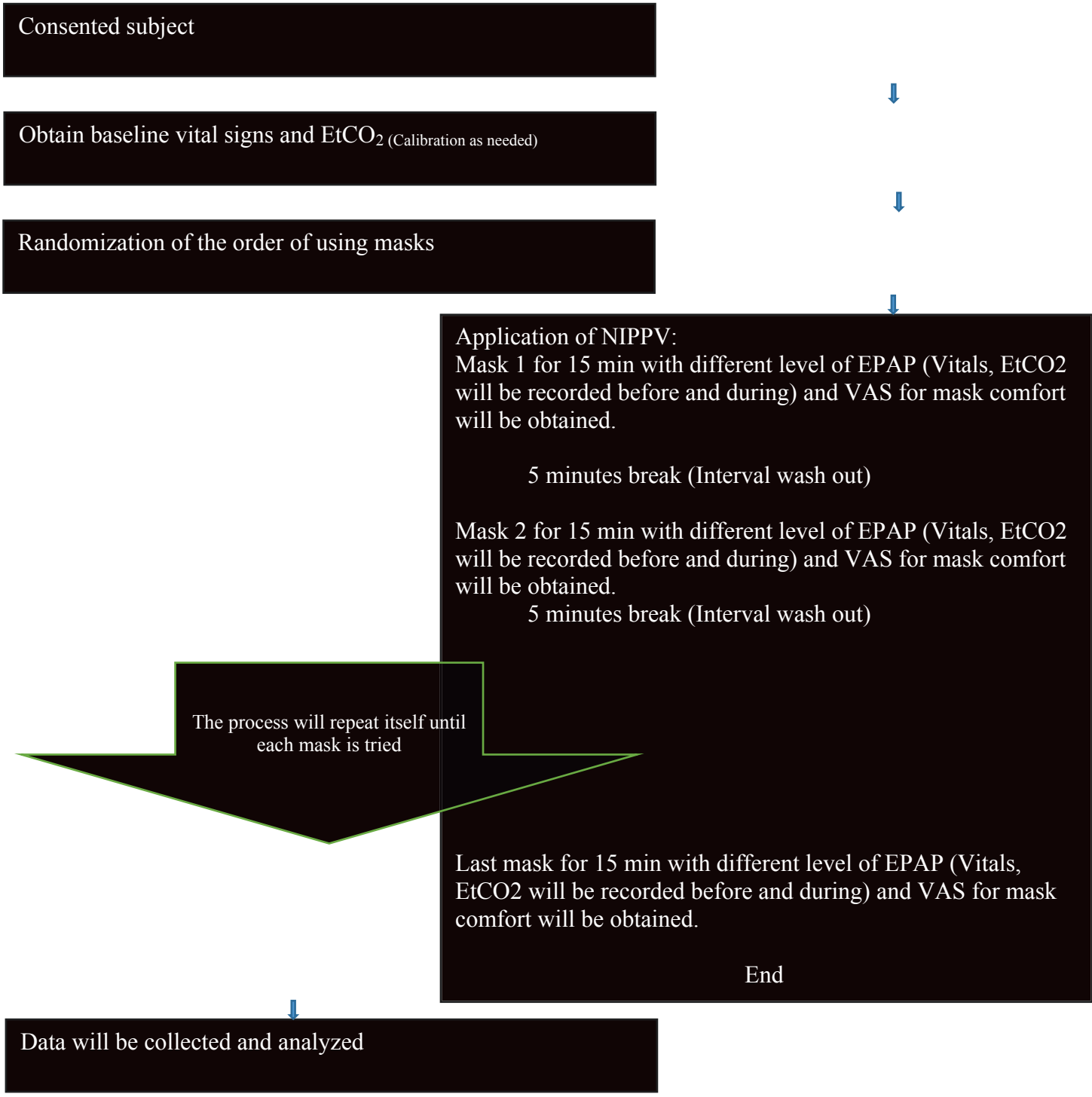
This study will be a randomized crossover trial that will be conducted at Rush University. Normal volunteers will be recruited from Rush University Medical Centers. Volunteers will be screened with inclusion and exclusion criteria and an informed consent is required in order for them to participate. Demographic (age, gender, ethnicity) will be obtained. Also, initial baseline vital signs (heart rate, blood pressure, respiratory rate, and oxygen saturation) will be obtained. $EtCO_2$ will be obtained at baseline and periodically using an oral/nasal sample line with the Capnostream™ 20p monitor (Medtronic, Minneapolis, MN). The study will use a double limb circuit ICU ventilator Puritan Bennett™ (Medtronic, Dublin, Ireland).

We will evaluate 4 NIPPV masks (2 oronasal masks and 2 full face masks). Oronasal masks will be labeled as group A and numbered as A1 and A2; while full face masks will be labeled group B and numbered as B1 and B2. Order of the masks will be randomly chosen in two steps. First steps will be choosing A or B then randomly assign mask in each of these groups. We will randomly assign mask in group A or B by drawing an initial mask from the group and then continue the sequence of masks from that point. For example, we randomly chose group A, then randomly chose A2, the sequence will be A2, A1. Then we would randomly choose B2, then the sequence would be B2, B1.

All subjects will perform 15 minutes on each mask followed by 5 minutes wash out interval between masks. EPAP levels will be 0, 2, 4, & 5 while IPAP remains at 5 higher than EPAP. EtCO2 will be collected at 4:00, 4:30 and 5:00 minute mark. These three measures should differ by less than 20% of their average. Also, subjective mask

comfort will be assessed via visual analog scale (VAS) with 1 referring to least comfortable and 5 being the most comfortable after 5 each EPAP setting.

Procedure figure:



4- Subject Population:

4.1. Population

Normal volunteers from Rush University.

4.2. Sample Size

20 healthy subjects.

4.3. Inclusion criteria:

4.3.1. Age > 18 years' old

4.4 Exclusion criteria:

4.4.1. Prior history of NIPPV as a patient.

4.4.2. Facial surgery or deformity

4.4.3. Ear infection

4.4.4. History of pulmonary or cardiac disease

5- Research recruitment and Consent Procedures:

5.1. Subjects will be recruited from students enrolled, faculty, and staff at Rush University.

5.2. An informed consent will be obtained by the investigators for all eligible candidate that meet the criteria.

6- Compensation:

Volunteers will be compensated with $ 25 Visa gift card

7- Special precautions:

7.1. Subjects refrain from eating at least 60 min before the study

7.2. Study will be stopped if HR change by 20% from baseline for more than 1 min.

7.3. Study will be stopped if subjects complain of shortness of breath

8- Confidentiality:

Subject names, date of birth, and contact information (email) will be in stored in REDCap. However, only de-identified data will be used for analysis.

9- Data Collection Instruments/ Data Collection Procedures/Data Analysis Plan:

Data for each subject will be recorded in REDCap

10- Variables:

Dependent: CO_2 clearance, level of comfort-

Independent: NIPPV interface, level of EPAP

11- Limitation:

It is performed on healthy subjects.

12- Analysis:

Data will be recorded in REDCap. Demographics data age (interval), gender (nominal), ethnicity (nominal) will be collected. HR (continuous), RR (continuous), SpO2 (continuous), $ETCO_2$ (continuous), EPAP (ordinal), IPAP (ordinal) will be collected. Means and Standard deviations will be calculated for aforementioned data. NIPPV interfaces number, sizes will be collected. Level of comfort will be collected; median and interquartile ranges will be calculated. Relationship between dependent variable ETCO2 and independent variable EPAP level will be analyzed by a Kruskal-Wallis test to determine if a significant difference exists. If a significant difference is found a Mann-Whitney U Test will be used to determine which EPAP levels significantly differ. Relationship between dependent variable comfort level and independent variable NIPPV interfaces will be analyzed a Kruskal-Wallis test to determine if a significant difference exists. If a significant difference is found a Mann-Whitney U Test will be used to determine which masks were significantly more comfortable.

Literature cited:

1- Otero DP, Dominguez DV, Fernandez LH, Magarino AS, Gonzalez VJ, Klepzing JV, et al. Preventing facial pressure ulcers in patients under non-invasive mechanical ventilation: a randomised control trial. J Wound Care 2017;26(3):128-136.
2- Thille AW, Contou D, Fragnoli C, Cordoba-Izquierdo A, Boissier F, Brun-Buisson C. Non-invasive ventilation for acute hypoxemic respiratory failure: intubation rate and risk factors. Crit Care 2013;17(6):R269.
3- Nakamura MA, Costa EL, Carvalho CR, Tucci MR. Performance of ICU ventilators during noninvasive ventilation with large leaks in a total face mask: a bench study. J Bras Pneumol 2014;40(3):294-303.
4- Ozsancak A, Sidhom SS, Liesching TN, Howard W, Hill NS. Evaluation of the total face mask for noninvasive ventilation to treat acute respiratory failure. Chest 2011;139(5):1034-1041.
5- Brill AK, Moghal M, Morrell MJ, Simonds AK. Randomized crossover trial of a pressure sensing visual feedback system to improve mask fitting in noninvasive ventilation. Respirology 2017.
6- Holanda MA, Reis RC, Winkeler GF, Fortaleza SC, Lima JW, Pereira ED. Influence of total face, facial and nasal masks on short-term adverse effects during noninvasive ventilation. J Bras Pneumol 2009;35(2):164-173.
7- Sadeghi S, Fakharian A, Nasri P, Kiani A. Comparison of Comfort and Effectiveness of Total Face Mask and Oronasal Mask in Noninvasive Positive Pressure Ventilation in Patients with Acute Respiratory Failure: A Clinical Trial. Can Respir J 2017;2017:2048032.
8- Medrinal C, Prieur G, Contal O, Villiot-Danger E, Doyle C, Reychler G, et al. Non-invasive ventilation: evaluation of CO2 washout by intentional leaking in three recent oronasal masks. A pilot study. Minerva Anestesiol 2015;81(5):526-532.
9- Samolski D, Calaf N, Guell R, Casan P, Anton A. Carbon dioxide rebreathing in non-invasive ventilation. Analysis of masks, expiratory ports and ventilatory modes. Monaldi Arch Chest Dis 2008;69(3):114-118.
10- Fraticelli AT, Lellouche F, L'her E, Taille S, Mancebo J, Brochard L. Physiological effects of different interfaces during noninvasive ventilation for acute respiratory failure. Crit Care Med 2009;37(3):939-945.
11- Pisani L, Mega C, Vaschetto R, Bellone A, Scala R, Cosentini R, et al. Oronasal mask versus helmet in acute hypercapnic respiratory failure. Eur Respir J 2015;45(3):691-699.