Use of PECO Air Purification in Hospital Rooms to Improve Health Outcomes for Pediatric Respiratory Distress

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Study Sponsor: Molekule, Inc.
Institution: Mercyhealth

Synopsis

This study will investigate the efficacy of a novel air purification technology, Photo Electrochemical Oxidation (PECO), has on pediatric patients hospitalized for respiratory distress. The study will take place at Mercyhealth Hospital – Rockton Avenue where all 23 pediatric rooms will be outfitted with portable PECO air purifying units. The main outcomes are length of stay and progression to ICU, which will be compared with historical controls.

Purpose of Study

The goal of this study is to assess whether using PECO to purify air in a hospital can improve health outcomes for pediatric patients with respiratory distress.

The results of this study will be used in three primary ways:

- As evidence to support installation of PECO in hospital HVAC systems to improve the standard of care for patients with respiratory distress
- Towards dissemination efforts through publication in a peer reviewed journal and presentation at national and international conferences
- For informing healthcare providers and stakeholders

There are no plans to repeat this study with other hospital partners.

Introduction

Pediatric respiratory distress is a leading cause of hospitalization for children. Respiratory distress can vary from viral or bacterial infections such as pneumonia, bronchiolitis, and Respiratory Syncytial Virus (RSV) to chronic respiratory diseases such as asthma. A few statistics that illustrate the size of the issue are listed below:

- Pneumonia and asthma were the 2nd and 3rd primary diagnosis for all pediatric (ages 1-17) hospitalizations in the US in 2011 (Pfuntner, A. et al., 2013).

- Pneumonia alone had estimated medical costs in 2009 in the US of almost $1 billion (Jain, S. et al., 2015).
- Asthma was the primary diagnosis for over 868,000 Emergency Department visits in the US in 2015 (CDC, 2015).
- RSV contributed to over 57,000 hospitalizations per year in the US for children under the age of 5 (CDC, 2018).

Among several factors, indoor air quality can exacerbate and contribute to respiratory distress especially in children. Mechanical filtration with High Efficiency Particulate Air (HEPA) filters has been a standard method of air purification for decades; however, a recent review of clinical trials, completed with HEPA air filters, found no rigorous evidence that use of HEPA filters conclusively improves asthma symptoms (McDonald, E. et al., 2012).

More recent research, with an adult population, has shown that home use of a new type of air purification technology, PECO, can reduce allergy and asthma symptoms over 4 weeks of use at home (Rao, N. et al. 2018 and Rao, N. et al. 2018 *in press*).

In addition to the peer reviewed health studies cited above, Molekule has shipped [redacted] portable PECO air purifiers to consumers throughout the US and has received almost universally positive feedback from consumers. Many consumers have reviewed the Molekule air purifier and have reported improvement in their asthma, allergies, and other respiratory symptoms associated with use of Molekule air purifiers (Molekule Reviews, 2018). There has been no indication of adverse health impacts from PECO for these users. [redacted]

PECO air purification technology was developed by Dr. Yogi Goswami, Distinguished Professor of Engineering at the University of South Florida, over the course of 20 years of research. PECO is a catalytic oxidation reaction that is far more efficient at generating hydroxyl radicals than traditional photocatalytic oxidation. The hydroxyl radicals fully oxidize bioaerosols down to innocuous end-products such as carbon dioxide, water vapor, and trace minerals (Goswami, D.Y., 2003, Zhang, Y. et al., 2013), effectively eliminating many airborne irritants.

Complete oxidation and destruction of bacteria and other bioaerosols by photocatalytic oxidation has been shown on a theoretical basis (Dalrymple, O.K., et al., 2010 and Wolfram, E.J., et al., 2002), and an experimental basis (Goswami, D.Y., et al., 1997). The more advanced and effective PECO technology, used by all of Molekule's products, has been experimentally verified to reduce the concentration of bacteria, viruses, and mold in the air by greater than 4 log in a single pass (ARE Labs, 2015) over a range of temperatures (ARE Labs, 2016). These data were collected using EPA good laboratory practice standards in support of Molekule's HVAC product achieving FDA 510(K) clearance as a Class II Medical Device (FDA, 2017).

In addition to destruction of bioaerosols, PECO can fully oxidize Volatile Organic Compounds (VOCs) (Olson, B., 2015), and destroy ozone (Olson, B., 2016), which are both lung irritants. PECO has also been verified by the California Air Resources Board (CARB, 2018) to not produce ozone (Intertek, 2017).

Given the findings from previous research on PECO, and feedback from [redacted] consumers operating Molekule's product in their home, we believe there is minimal risk to installing Molekule's PECO portable air purifying units in hospital rooms for this study.

Here we plan to investigate the impact PECO air purification can have on pediatric respiratory distress when deployed in a hospital setting. Pediatrics were chosen as the demographic for this study for three reasons: adults with allergies and asthma were previously shown to respond well to use of an at home PECO air purifier (Rao, N., et al., 2018 *in press*), there is great interest to study this in a controlled pediatric population, and respiratory distress is a leading cause of hospitalization for children.

Over the course of this study, portable PECO air purifying units will be installed in all pediatric rooms at the Mercyhealth Hospital - Rockton Avenue. This study will compare health data from a current cohort of pediatric patients in rooms outfitted with the portable PECO air purifying units to historical lengths of stay, readmission rates, and various other metrics for pediatric patients suffering from respiratory distress.

Hypothesis

Various health outcomes (as listed in the Methods section) will be improved for children with infectious or non-infectious respiratory distress when PECO is continuously used to purify air in patient rooms compared to historical records.

Methods

Setting

General pediatric ward and ICU rooms (excluding NICU rooms) at the Mercyhealth Hospital - Rockton Avenue will have PECO portable units installed.

Pediatric Rooms Receiving PECO portable units:

- 4 Semi-Private Rooms - 2 beds per room - 2 PECO portable unit per room on each patient's side of the room
- 12 Private Rooms - 1 bed per room - 1 PECO portable unit per room
- 7 PICU Private Rooms - 1 bed per room - 1 PECO portable unit per room
- Total Number of Units: 27 + 4 Backup Units = 31 Units

Participants

Inclusion: All pediatric patients who are admitted to the Mercyhealth Hospital - Rockton Avenue following the Start Date and have infectious or non-infectious respiratory distress as defined by the following ICD codes will be included in the study:

- J00-J06: Acute upper respiratory infections
- J09-J18: Influenza and pneumonia
- J20-J22: Other acute lower respiratory infections
- J30-J39: Other diseases of upper respiratory tract
- J40-J47: Chronic lower respiratory diseases
- J60-J70: Lung diseases due to external agents
- J80-J84: Other respiratory diseases principally affecting the interstitium
- J85-J86: Suppurative and necrotic conditions of the lower respiratory tract
- J90-J94: Other diseases of the pleura
- J95-J95: Intraoperative and postprocedural complications and disorders of respiratory system, not elsewhere classified

Exclusion: The following patients will be excluded from the study:

- Any patient admitted to the NICU
- Patients in the ER only
- Any patient with non-respiratory conditions
- Adults

Pre-implementation Group (Comparison group): The pre-measure will be all pediatric patients who meet the above criteria from August 1, 2017-August 7, 2018.

Consent

Consent will not be needed since there are no known risks using air purifiers with PECO technology. Furthermore, both pre-clinical and clinical studies show the potential for health benefits from air purification with PECO technology (Rao, N. et al. 2018 and Rao, N. et al. 2018 *in press*). The data do not show any harm or irritants due to the use of PECO air purification technology, and PECO can reduce many harmful irritants, pathogens, and allergens in the air. As such, the investigation involves no more than minimal risk.

Because this study would require a high volume of patients who will have shifting respiratory statuses and the nature of using an air purifier, this study could not be practically carried out without a waiver of consent. Given the no more than minimal risk status of this study, the rights and welfare of the research participants will not be adversely affected. If any patient, or family member, requests the unit be removed, their wishes will be honored and data will not be reported.

Length of Study

This study will enroll participants from August, 2018 through December 31, 2018. Over a 5 month period, the study anticipates approximately 166 participants.

Proposed Start Date: August 7, 2018

Variables & Data Collection

Health data will be tracked in Epic in accordance with existing Mercyhealth procedures and policies.

The following list of data will be tracked and evaluated as clinical endpoints for all pediatric patients with respiratory distress as defined by the ICD codes listed above:

Age
Sex
Race
Admitting Diagnosis
Principle Diagnosis
Length of Stay (in days) in PICU
Length of Stay (in days) total
Was patient intubated? (yes/no)
If yes, duration of intubation (in hours)
List of medications administered during inpatient stay
Was a nebulizer used? (yes/no)
If yes, number of days used
If yes, number of treatments each day
If yes, nebulized medication used
Was nasal cannula oxygen used?
If yes, number of days used
If yes, number of hours each day
Was patient readmitted to inpatient status for any reason within 30 days of this discharge? (yes/no)
If yes, # of days from index discharge to readmission date
Principle diagnosis for readmission stay
Was noninvasive ventilation used? (yes/no)
If yes, type of NIV
If yes, number of days used.
If yes, number of hours each day
List of secondary diagnoses (comorbidities)
Were blood cultures or cultures from a respiratory source collected? (yes/no)

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If yes, what type of culture was done?
If a culture was done, what day of hospitalization was the culture ordered?
If a culture was done, was it positive?
If yes, what organism was found?

Data will be collected and tabulated by a trained Nurse reviewing medical records. Data will be tabulated in a password protected Excel file and sent via secure email to Molekule. Data will be stored at Molekule on a secure server in a password protected excel file.

In addition, Molekule will track unit usage data through a WiFi connection.

Statistical Methods

Prior to analysis all identifiable information (e.g. name, date of birth, zip codes etc) will be removed and only de-identified data will be used for analysis. Descriptive statistics (e.g. frequency and relative percentages, means, standard deviations) will be used to describe demographic characteristics, compliance and comorbidities of included participants. The change in outcomes following intervention for continuous variables will be compared to historical controls using paired t-tests and summarized as mean differences along with 95% confidence intervals (CI). For the ease of interpretation summary measures from continuous data may be converted into odds ratio along with 95% CI. For binary/categorical variables the difference across compared groups will be assessed using the chi-square test and summarized as odds ratio along with 95% CI. We also plan to perform either General Linear Model or logistic regression analysis to adjust for confounding across compared groups. The statistical significance will be set at $p<0.05$ for all comparisons. All analyses will be performed using SPSS statistical analysis software version 24 or similar by a biostatistician. The statistician will analyze de-identified data only.

Study Implementation

PECO Portable Unit Installation

1. Prepare PECO Portable Units
    a. Molekule will prepare 31 units and ship to Mercyhealth Hospital - Rockton Avenue
    b. Address:
    Mercyhealth Hospital - Rockton Avenue
    2400 N Rockton Ave
    Rockford, IL 61103
2. Install PECO Portable Units
    a. Molekule will be onsite to install all PECO Portable Units in hospital rooms

i. Molekule will need assistance from Mercyhealth staff during installation for direction to the appropriate rooms and consultation on placement

b. Molekule, with help of Mercyhealth staff, will place units in each of the 27 pediatric rooms
   i. Units will be positioned as close to the patient as feasible
   ii. The units come standard with a 6-ft cord and a 3-prong plug
   iii. The units draw approximately 100 Watts, and are suitable for a standard 120 VAC outlet

c. Molekule will connect each unit to the Mercyhealth WiFi system
   i. Molekule may need assistance from Mercyhealth IT department if there are certain firewall restriction etc.

d. Molekule will register each unit to a study-specific account on the Molekule phone app

3. Train Staff in Unit Operation
   a. Molekule will hold a training session for nurses and all other relevant staff on operation and maintenance of the units.
   b. Molekule will provide an operation reference card for the units
   c. Molekule will be available for technical support throughout the study

PECO Portable Unit Operation

1. Operation
   a. All units will be controlled locally by nurses or other Mercyhealth staff who have been appropriately trained by Molekule
   b. Units must stay in Auto mode with the light on and will operate 24 hours a day, 7 days a week
      i. Units should be positioned as close to the bed as possible
      ii. If a specific patient is bothered by the blue light or by the noise of Auto mode, the light may be turned off or to Silent mode at night; however, it should not remain in silent mode or with the light off for more than 8 hours
      iii. If the unit's light is turned off, the unit is turned out of Auto, or the unit is turned off for any reason Mercyhealth staff should notify Molekule
   c. Units will be connected to WiFi and operation will be remotely monitored, but never operated remotely by Molekule
2. Unit Filter Replacement
   a. Molekule will ship Pre-Filters and Nano-Filters to Mercyhealth and instructions for filter change out at the appropriate times
      i. Routine Maintenance
         1. Mercyhealth staff will change Pre-Filters every month
         2. Mercyhealth staff will change Nano-Filters every month
3. Unit Cleaning
   a. External cleaning of machine will follow standard room cleaning procedures for hard surfaces set forth by Mercyhealth.

b. If in an isolation room, the external surfaces of the machine will follow standard terminal cleaning procedures set forth by Mercyhealth.

Data Analysis

1. Health data from Mercyhealth Hospital - Rockton Avenue will be aggregated and shared with Molekule for analysis by Mercyhealth staff
    a. The de-identified data listed in the Variables and Data Collection Section will be required for any pediatric patient with a diagnosis of the ICD codes listed above
2. Health data and study progress will be evaluated at the timescale listed below in the Timeline section
3. Molekule will follow all data privacy and storage guidelines provided by Mercyhealth under our Mutual Non-Disclosure Agreement
4. Patient identifying information will be de-identified prior to analysis by Molekule. De-identified data will be stored in a secure password protected location. Only the investigators will have access to this information and the password.

Filter Sampling

In addition to the clinical study described above, we plan to investigate the potential for mold and bacterial growth on filters within the air handling units of hospitals in comparison to the filters within the portable PECO units.

PECO can break down bacteria and mold while standard mechanical filters, which are typically in hospital Air Handling Units (AHUs) can only capture some mold and bacteria. Upon capture, these microbes may reproduce and potentially escape back into the air stream. Since respiratory distress can be aggravated by bacteria and mold in the air, this additional investigation will partially show why we see the clinical results described above.

We plan to collect used filters from the PECO portable air purifying units and used filters from the AHUs that service the pediatric ward, and an AHU that services another part of the hospital. The used filters will be sent to a commercial lab and be analyzed for total bacteria and mold.

The collection and analysis will follow this procedure on a monthly basis coincident with the filter change out:

- Collect 3 Nano-Filters from 3 separate rooms in the pediatric ward
- Collect 1 filter from the AHU servicing the pediatric ward
- Collect 1 filter from a designated AHU servicing a different area of the hospital
- Place all filters in individual plastic bags
- Pack with ice
- Ship to commercial lab for bacterial, and mold analysis
- Note: During the baseline sampling for the AHUs, 1 PreFilter and 1 FinalFilter will be collected from both the AHU servicing the pediatric ward and the reference AHU.

Similarly, at the first monthly change out, 3 Nano-Filters along with 3 PreFilters will be collected from the units in the pediatric ward. After analysis of first set of AHU and Unit filters, a decision will be made as to which filter (i.e. Pre vs Final and Pre vs Nano) will be sampled going forward.

This analysis will occur for 3-6 months depending on initial results.

The lab will follow this general procedure for obtaining total bacteria and total mold for each filter:

- Cut out a filter swatch anywhere from 1 sq inch to 4 sq inch depending on the sample type
- Vortex or sonicate that in 1-10 mL of Phosphate Buffer Saline (PBS) solution as needed to suspend and recover the microbes
- Plate solution on TSA for bacteria and MEA for fungi
- Count the colony forming units on each plate

Timeline

Week	9-Jul-2018	16-Jul-2018	23-Jul-2018	30-Jul-2018	6-Aug-2018	1-Oct-2018	31-Dec-2018
Finalize Protocol							
IRB Approval		IRB meets July 16					
Units Shipped							
Units Arrive at MH							
Study Start					Start		
Evaluation						80 patient evaluation	~166 patient evaluation

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