Table of contents

Letter from the Editor .................................................................................................................................3

DOES THE MINIMAL OCCLUDING VOLUME TECHNIQUE RESULT IN SAFE CUFF PRESSURES?


Letter from the Editor

One of the ongoing requirements of LSC: Kingwood College’s Associate in Applied Science Degree in Respiratory Care includes participation in the creation of this magazine for RSPT 2243 Research in Respiratory Care. Students formed teams that designed research projects for application to this magazine during the semester.

Some of the requirements of this course included membership in a weekly journal club of current articles from AARC’s Journal of Respiratory Care as well as active participation in writing the four papers in our journal based on their independent research. Students were also expected to provide peer-review of other teams’ papers.

The spring 2013 editing board consisted of the following: Audrey Morales, Brandy Fletcher, Tabatha Lewis Mary Perry, S.R.T., Kara Bragg Fallon Crawford, Jansen Gonzales, and Jessica Stolte Sonya Cappel, Sophja Cheam, Yolanda Contreras, Vanessa Underwood-Gonzalez, Rochelle Harris, Vanessa Chairez, Joann Jove and Melissa Phillips.

In addition to the above editors, who reviewed content, this year we were joined by Professor Karen R. Gee and her English class who reviewed these papers for proper APA formatting and references.

We want to thank Professor Gee for her involvement in the creation of this magazine, and as usual, Kenny McCowen for his continued support of the research class. As usual, I want to personally thank my peers in the respiratory care faculty who reviewed and questioned my students’ oral presentation of their research projects. I could not teach this class without your input.

This semester we had to call on the Lonestar College’s internal review board for input. The members of Lonestar College’s IRB spent several weeks reviewing one of our projects and making recommendations so we could start work. That was a lot of hard work which we appreciate.

The graphic on the cover of this edition was created by Gus Buzbee and his Photoshop.

Elizabeth Kelley Buzbee A.A.S., R.R.T-N.P.S., R.C.P.
DOES THE MINIMAL OCCLUDING VOLUME TECHNIQUE RESULT IN SAFE CUFF PRESSURES?

Audrey Morales, S.R.T.
Brandy Fletcher, B.S., S.R.T.
Tabatha Lewis, C.N.A., S.R.T
Mary Perry, S.R.T

ABSTRACT

INTRODUCTION: The purpose of this study is to determine if the pressures that are used with the minimal occluding volume technique are within the range of 20-30 cm H₂O. OBJECTIVE: Does the minimal occluding volume technique (MOV technique) for endotracheal tube cuff inflation results in pressures that are within the safe range? METHODS: We recruited 2 instructors and 4 respiratory care students. Participants performed the minimal occluding pressure technique 3 times on an endotracheal tube cuff that was inserted into a mock trachea that was constructed of 5 inch flex hose. Without the participant’s knowledge of the results, the cuff pressures were measured at the end of each trial. RESULTS: The combined cuff pressures between students and professors ranged from 26-102 cm H₂O. The mean professors’ cuff pressures was 56 cm H₂O while the mean students’ cuff pressures was 63.5 cm H₂O. Out of 18 trials only 2 were within recommended range. CONCLUSION: Our research demonstrated that the cuff pressures were higher than recommended when using the MOV technique. It is of concern that the resulting pressures were so high, as this can compromise patient safety and lead to complications of cuff over-inflation such as tracheal injury and longer stay in the hospital.

INTRODUCTION

Effective managing of endotracheal tube cuff pressures is vital in caring for an artificial airway. The function of the endotracheal tube cuff is to seal the airway, preventing aspiration of pharyngeal contents into the trachea. It also prevents leaks past the cuff during positive pressure ventilation. Some of the other issues that can occur with endotracheal cuffs are over-inflation that can damage the tracheal mucosa and under-inflation that can lead to hypoventilation of the patient.

The minimal occluding volume technique (MOV) is a quick method for inflating a cuff when a manometer is not available. The technique can be done by connecting the pilot balloon to the syringe and slowly inflating the cuff during a positive pressure breath and stopping when there is no longer an audible leak (Egan, Scanlan, Wilkins, & Stoller, 1999). One group recommended deflating the cuff completely and gradually inflating 0.2 – 0.5 ml with a 10 ml syringe and listening with a stethoscope over the thyroid cartilage area where air leaks will be audible upon auscultation (Shock Team, 2013).

Maintaining cuff pressures in the range of 20-30 cm H₂O (centimeters of water pressure) is critical to prevent damage. Approximately ten percent of mechanically ventilated patients develop tracheal complications due to high-volume, low-pressure cuffs (Guyton, Banner & Kirby, 1991). The purpose of this
study is to determine if the pressures that are used with the minimal occluding volume technique are within the range of 20-30 cm H.O. We will test the hypothesis that the pressures will depend on the technique of the technician and that the pressures are at a higher range than what is recommended. Does the minimal occluding volume technique (MOV technique) for endotracheal tube cuff inflation result in pressures that are within the safe range?

**METHODOLOGY**

**EQUIPMENT USED**

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Manufacturer</th>
<th>Address</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maquet Lung</td>
<td>Kehler Strasse 31</td>
<td>76437 Ratsatt, Germany</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6006832EO37E</td>
</tr>
<tr>
<td>Rusch Endotracheal Tube</td>
<td>Teleflex Medical</td>
<td>9217 Weck Dr.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Research Triangle Park, NC 27709</td>
</tr>
<tr>
<td>Duct Tape</td>
<td>Pennzoil #14712</td>
<td>5330 Fox St.</td>
</tr>
<tr>
<td></td>
<td>Navajo Mfg. Co</td>
<td>Denver, Co. 80216</td>
</tr>
<tr>
<td></td>
<td>Blue corrugated tubing</td>
<td>Portox 1&quot; Response Adult</td>
</tr>
<tr>
<td></td>
<td>Manual Resuscitator</td>
<td>Model 8500P</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5100 Tice St.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ft. Myers, FL 33905</td>
</tr>
<tr>
<td></td>
<td>Exel Int. 10 mL Disposable Syringe, latex free</td>
<td>26265 (x1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Exelnt International, Co.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5840 W. Centinela Ave.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Los Angeles, CA 90045</td>
</tr>
<tr>
<td></td>
<td>Posey Cufflator #8199, SN 9310176</td>
<td>Posey Company</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5635 Peck Road</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Arcadia, CA 91006</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Prestige Medical Stethoscope</td>
</tr>
<tr>
<td></td>
<td></td>
<td>#1268126</td>
</tr>
<tr>
<td></td>
<td></td>
<td>8600 Wilbur Ave.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Northridge, Ca. 91324</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Volrath Cafeteria Meal Tray</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Apple Iphone 5: Stopwatch and Camera</td>
</tr>
</tbody>
</table>

**THE MOCK TRACHEA SET UP**

1. The research team validated the Posey Cufflator to ensure pressures were accurately read by occluding the port at a pressure of 120 cm H.O for 3 seconds.
2. Attach tubing to mock trachea with duct tape

3. Tape down mock trachea on tray for stability

4. Test the cuff for leaks prior to insertion

5. Insert size 8mm endotracheal tube midway in the corrugated tubing

6. Inflate endotracheal tube cuff with 10 cc’s of air with a 10 mL syringe

7. Moisten tubing with 3cc of water above the cuff to create gurgle sound in the airway

8. Attach the resuscitator bag to endotracheal end connector to mock aeration of lung

The Experiment

One researcher explained the MOV technique to the participants for approximately 3-5 minutes. Each participant practiced at least once under the observation of the researcher. This took about 2-3 minutes.

The participant performed the MOV technique by deflating the cuff slowly to the point where the participant can hear an air leak on positive pressure inspiration and re-inflates to the point where the leak is no longer audible 2-3 minutes during positive pressure.

The participant then turned away while the researcher measured the endotracheal tube cuff pressure with the manometer, while another researcher recorded the pressure without speaking out loud.

After researchers deflated the cuff and prepped the setup as before by adding water, the participant repeated the cuff inflation technique two more times.
With the approval of the Lonestar Kingwood College Internal Review Board, the team recruited 6 instructors and respiratory care students. Eligible students had completed the chapter on airways in Fundamentals of Respiratory Care II. Students who have not completed airways chapter in RSPT 1431 Fundamentals II have been excluded due to the lack of exposure and instruction on the principles of airway care and endotracheal tube maintenance.

The Internal Review Board did not require consent from the participants according to exemption 45 CFR 46.101(b)2. Regardless, no data was recorded that would link these study results to specific individuals. Any identifiable data was kept in a secured area and destroyed after the study. Prior to the experiment, the researchers explained a short description of steps of the minimal occluding volume technique based on Egan’s Fundamentals and Shock Team. The participant practiced this technique one or more times before he/she performed the procedure on the mock airway.

While the researchers observed, the participant performed the minimal occluding pressure technique on an endotracheal tube cuff that was inserted into a mock airway of a mock lung. The technique was done three times and pressure was read each time without the participant’s knowledge of the pressure results. This completed the participant’s role. The contributors were only identified as “respiratory care student” or “respiratory care professor”.

After data was collected, data was input into MS Excel for calculation of mean, median, standard deviation and other data. Using Excel and MS PowerPoint, graphics were created.

## RESULTS

<table>
<thead>
<tr>
<th></th>
<th>Trial 1</th>
<th>Trial 2</th>
<th>Trial 3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Professor</strong></td>
<td>70 cm H.O</td>
<td>76 cm H.O</td>
<td>26 cm H.O</td>
</tr>
<tr>
<td><strong>Student</strong></td>
<td>38 cm H.O</td>
<td>54 cm H.O</td>
<td>102 cm H.O</td>
</tr>
<tr>
<td><strong>Professor</strong></td>
<td>46 cm H.O</td>
<td>48 cm H.O</td>
<td>70 cm H.O</td>
</tr>
<tr>
<td><strong>Mean</strong></td>
<td>51.3 cm H.O</td>
<td>59.3 cm H.O</td>
<td>66 cm H.O</td>
</tr>
<tr>
<td><strong>Medium</strong></td>
<td>46 cm H.O</td>
<td>54 cm H.O</td>
<td>70 cm H.O</td>
</tr>
<tr>
<td><strong>SD</strong></td>
<td>16.653328 cm H.O</td>
<td>14.7422939 cm H.O</td>
<td>38.15756806 cm H.O</td>
</tr>
</tbody>
</table>

Endotracheal tube 8.5cm, n=3

The percent change between trial 1 and trial 3 for the first professor was 63%. The single students percent change from trial 1 to trial 3 was -108%. The second professors’ percent change from trial 1 to trial 3 was -52%. The entire group averaged 59 cm H.O on the 8.5 endotracheal tube. The cuff pressures ranged from 26-102 cm H.O.
The entire group of students averaged a cuff pressure of 63.5 cm H₂O. The students’ pressures ranged from 26-110 cm H₂O. The percent change between trial 1 and trial 3 for the entire students ranged from 17%-63% with a size 8.0mm endotracheal tube.

In the graph below P stands for professor and S for student.

<table>
<thead>
<tr>
<th>Student</th>
<th>Trial 1</th>
<th>Trial 2</th>
<th>Trial 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>110 cm H₂O</td>
<td>80 cm H₂O</td>
<td>90cm H₂O</td>
<td></td>
</tr>
<tr>
<td>72 cm H₂O</td>
<td>26 cm H₂O</td>
<td>40cm H₂O</td>
<td></td>
</tr>
<tr>
<td>50 cm H₂O</td>
<td>40 cm H₂O</td>
<td>60cm H₂O</td>
<td></td>
</tr>
<tr>
<td>38 cm H₂O</td>
<td>54 cm H₂O</td>
<td>102cm H₂O</td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>67.5 cm H₂O</td>
<td>50 cm H₂O</td>
<td>73cm H₂O</td>
</tr>
<tr>
<td>Medium</td>
<td>61 cm H₂O</td>
<td>47 cm H₂O</td>
<td>75cm H₂O</td>
</tr>
<tr>
<td>STD Deviation</td>
<td>31.63858404 cm H₂O</td>
<td>23.03620339 cm H₂O</td>
<td>28.21347196 cm H₂O</td>
</tr>
</tbody>
</table>

ETT tube 8.0

The entire group of students averaged a cuff pressure of 63.5 cm H₂O. The students’ pressures ranged from 26-110 cm H₂O. The percent change between trial 1 and trial 3 for the entire students ranged from 17%-63% with a size 8.0mm endotracheal tube.

In the graph below P stands for professor and S for student.
Students 1-4 Trials of cuff pressures in cm H$_2$O

The professors’ mean cuff pressures were 56 cm H$_2$O, while the mean of the students’ cuff pressures was 63.5 cm H$_2$O. The percent change varied from 27%-66% between both the professors and students. These values were obtained by using the high and low cuff pressures that ranged from 26 cm H$_2$O-110 cm H$_2$O of all participants.

DISCUSSION AND CONCLUSION

Our research demonstrated that the cuff pressures were higher than recommended when using the MOV technique. The results of our trials indicate that only 11% of our trials maintained a normal range (20-30 cmH$_2$O) in cuff pressures.

A clinical trial of anesthesia providers and patients in the hospital reported similar findings. Tracheal pressures obtained by “estimation techniques” ranged from 6 to 60 cmH$_2$O. Analysis revealed that less than one third of the anesthesia providers inflated the cuff within an ideal range (Norwood, Stewart, Seacrest, & Zachary 2003).

The difference in percent change between professors and students could be based on experience, which may contribute to lower pressures. A person who has been measuring cuff pressures for years is more likely to recognize excessive pressures, when compared to someone with just 1 year of experience.

It is of concern that the resulting pressures were so high, as this can compromise patient safety and lead to complications of cuff over-inflation such as tracheal injury and longer stay in the hospital.

A limitation of our study was the wide variability of the cuff pressures. Were the variations of the cuff pressures the result of technique, or the rigid plastic of the mock trachea? The substitution of a mock trachea could have lead to the high-pressure readings that were recorded. Hearing the air leak through the tubing was difficult, so we modified it by adding the water in the tubing, which created a gurgling noise. For future studies, it is recommended that a human or animal cadaver trachea be utilized to obtain more accurate cuff pressures.

In order to create a tight seal with no air leak with the plastic mock trachea, the researchers used 10cc of air to inflate the cuff which is comparable to what it would take to inflate an adult patient that had been intubated. In theory, the pressures should have been within normal range after performing the MOV technique but they were not for reasons we do not understand.

The number of participants used to collect data was small. It would be helpful to have more participants for future studies.

According to our studies 89% of the pressures were above normal range, which would be clinically
significant if it represented a larger population of therapist practicing this technique in a hospital setting. A best practice recommendation suggests alternate techniques such as using a manometer.

In conclusion, the use of a manometer is more accurate than the MOV technique. Accurate cuff pressures can help minimize ischemia, stenosis of the tracheal mucosa, aspiration, decreased perfusion to the trachea, and total obstruction of tracheal blood flow. Over-inflation of the cuff with a pressure of 34 cm H₂O can cause damage. On the other hand, pressures as low as 27 cm H₂O can reduce tracheal blood flow by 75% at the cuff site.

Measurements between 20-30 cm H₂O are a standard to reduce the risk of injury to an intubated patient. While effort is made to ensure lower pressures by using the MOV technique, the results of this study shows that the technique is not adequate to maintain pressures within normal range.

If the studies were done with a human or animal cadaver trachea would the cuff pressures be more in line with normal pressures? If those pressures were more in line; is the method taught in medical courses an accurate form of training or would it be best to train on a human or animal cadaver?
REFERENCES


COMPARISON OF SUSTAINED INFLATION Pressures
ON STATIC COMPLIANCE OF PRESERVED PIG LUNGS
DURING MECHANICAL VENTILATION: IS MORE
BETTER?

Kara Bragg S.R.T.,
Fallon Crawford B.S., S.R.T.,
Jansen Gonzales A.A., A.S. S.R.T.,
Jessica Stolte A.F.A., S.R.T.

ABSTRACT

BACKGROUND: The purpose of this study was to determine which pressure and inspiratory time hold during sustained inflation (SI) would best increase lung compliance in preserved pig lungs. Which of the four versions of sustained inflation (SI) would result in better recruitment of lung alveoli? METHODS: A pair of preserved pig lungs were manually deflated then ventilated using pressure control ventilation SERVO-i with pressures of 20 cm H2O, set rate of 10 breaths/min, PEEP of 5 cmH2O, FIO2 21%, inspiratory time 0.90 seconds, inspiratory rise time 0.15 seconds, and trigger 3 L/min. The baseline static compliance was measured. During the sustained inflation technique we switched to continuous positive airway pressure (CPAP) mode and used end-expiratory pressures of 40 and then 50 cmH2O for 30 and then 40 seconds for a total of twelve trials. RESULTS: The mean percent change of static compliance for 40/30 rose 151.8819188%. The percent change for 40 cmH2O for 40 seconds was 209.3621399%. The percent change for 50/30 rose 87.78159603%. The percent change in compliance for 50/40 trial was 153.9354839%. CONCLUSION: The moderate level of recruitment (40 cmH2O for 40 seconds) trial was the most effective at recruiting lung alveoli and the 50/30 was the least effective. Just as PEEP studies demonstrate that there is no single “best” PEEP, this study implies that RCP’s may have to experiment and reevaluate the results frequently to protect their patients.

INTRODUCTION

Restrictive lung diseases are important causes of morbidity and mortality in the United States (Ford, Mannino, & Redd, 2003). Restrictive lungs cannot expand at normal levels and are restricted from filling by either scarring from disease, an anatomical malformation, environmental exposure, or edema.
When persons with a restrictive defect try to breathe, they are unable to completely fill their lungs due to stiffness from a decreased total lung capacity (TLC). If a pulmonary function test is performed, typically the following will be less than 80% of predicted values: functional residual capacity (FRC), residual volume (RV), and total lung capacity (TLC) (Dexter, Heuer, & Wilkins, 2010).

There are two main types of acute restrictive diseases that affect lung compliance, which are named according to their severity: acute lung injury (ALI) and acute respiratory distress syndrome (ARDS). One of the criteria used to define and distinguish acute lung injury (ALI) from acute respiratory distress syndrome (ARDS) is by calculating the \( \text{PaO}_2/\text{FiO}_2 \) (P/F) ratio.

The \( \text{PaO}_2/\text{FiO}_2 \) (P/F) ratio is a reliable index of gas exchange, when a range of FIO\(_2\) settings are applied (Heuer, Kacmarek, & Stoller, 2013). A \( \text{PaO}_2/\text{FiO}_2 \) (P/F) ratio that ranges between 200-300 mmHg is associated with acute lung injury (ALI) and a \( \text{PaO}_2/\text{FiO}_2 \) (P/F) ratio of less than is 200 mmHg is associated with acute respiratory distress syndrome (ARDS) (Dexter, Heuer, & Wilkins, 2010). Acute lung injury (ALI) and acute respiratory distress syndrome (ARDS) are characterized by regions of collapsed lung due to changes in surfactant, surface tension in the alveoli air sacs, and lung water (Kheir & et al., 2013). Collapsed lung regions result in decreased lung compliance, which makes breathing difficult.

A lung recruitment maneuver (RM) is a technique that is used to expand stiff lungs. Lung recruitment should improve ventilation, gas exchange, and increase lung compliance. Laplace’s law states that as the radius of a bubble increases, the pressure to inflate the lung will decrease and the lung is less likely to deflate (Heuer, Kacmarek, & Stoller, 2013). For example, if there were two lung sacs with the same surface tension, but different in size, the lung sac with the smaller radius will have a greater deflating pressure and will be more likely to collapse than the larger lung sac.

There are several types of recruitment maneuvers (RM), but for this study, four different versions of sustained inflation (SI) were compared. Sustained inflation (SI), or inspiratory hold, essentially involves application of sustained peak pressure for a specified amount of time. Its objective is to inflate the lung alveoli with a high initial opening pressure which will enable them to “pop” open and allow them to participate in gas exchange (Bogossian, Jauncey-Cooke, & East, 2009). The sustained inflation technique involves applying high pressures at a range of 40-50 cmH\(_2\)O with an inspiratory time hold of 30-40 seconds.

The purpose of this study was to determine which pressure and inspiratory time hold during sustained inflation (SI) would best increase lung compliance in preserved pig lungs. The biological question was to determine which versions of sustained inflation (SI) would result in better recruitment of the alveoli? The present study was undertaken to test the hypothesis that 50 cmH\(_2\)O for 40 seconds would be more effective at recruiting lung alveoli and increasing lung compliance rather than lower pressures for shorter times.

**METHODOLOGY**

- **Apron/Gown.** SANI-SURE, China
- 2 boxes of gloves: 1 [M] nitrile powder-free, Microflex Corporation, Reno, NV 89533-2000; [L] powder-free nitrile, Digiticare Corporation, Los Angeles, CA 90064, USA
- 1 Set Preserved Pig Lungs - Donated by Lone Star College
- Scotch Duct Tape, Part # 051131854925, Serial # 3311
- **Endotracheal tube.** Murphy eye, high volume, low pressure cuff, REF 112082075, size tube ID mm7.5, Tube OD mm 10.0; Teleflex Medical, Kaming, Malaysia
• 1 Maquet SERVO-i Ventilator System V4.0, Model #6449701, Serial #136253
• 2 [60 inches in length] standard corrugated tubing
• 2 Pulmoguard Disposable Bacterial/Viral Filter, Reorder #: F0100, Form #: 27-0029
• Stopwatch-Apple iphone 5, 1 Infinite Loop

VALIDATION OF MEASURING DEVICES

The devices and equipment that were used were calibrated and/or validated prior to use. The ventilator was validated by passing every component of the pre-use check/EST except for the FIO₂ according to the manufacturer’s recommendation.

PREPARING THE LUNG

Step 1- Put on appropriate personal protective equipment (PPE), such as gown, gloves, and goggles

Step 2- Assemble the lung stand so that the lungs will hang freely

Step 3- Insert endotracheal tube into the opening of the pig lung

Step 4- Inflation of cuff turned out to be unnecessary because the 7.5 endotracheal tube (ETT) was an exact fit.

VENTILATOR PARAMETERS

The preserved pig lungs were ventilated using pressure controlled ventilation on the SERVO-i with pressures of 20 cm H₂O, set rate of 10 breaths/min, PEEP was set to 5 cmH₂O, FIO₂-21%, Inspiratory time- 0.90 seconds, Inspiratory rise time- 0.15 seconds, and Trigger- 3 L/min. During the sustained inflation technique we switched to continuous positive airway pressure (CPAP) mode and used end-expiratory pressures of 40 to 50 cmH₂O for 30 to 40 seconds.
STUDY PROCEDURES

Researchers 1 & 2 performed the experiment, while a third researcher recorded the findings on the data flow sheet. Researcher 4 photographed the process and assisted others when needed. At the end of the study, there were a total of 12 trials, 3 trials per pressure and inspiratory time hold.

1. Set up SERVO-i ventilator with the ventilator parameters as stated previously
2. Place the animal lung on the ventilator by connecting the endotracheal tube to the bacterial filter, which is attached at the end of the wye adaptor on the adult circuit
3. Manually collapse the preserved pig lung between each trial using gloved hands; this will decrease the lung compliance and allow the measurement for baseline parameters
4. For trial one, apply an end-expiratory pressure of 40 cmH₂O for 30 seconds
5. Switch back to initial settings with pressure control ventilation and quickly perform an inspiratory hold for 2 seconds to determine the plateau pressure. Then, on the second breath after the recruitment maneuver record the plateau pressure, PEEP, and exhaled tidal volume
6. Repeat steps 3-5 using the same pressures for the same amount of time two additional times
7. For trial two, repeat steps 3-5 with an end-expiratory pressure of 40 cmH₂O for 40 seconds (measured with a stop watch) and record the data on a flow sheet
8. Repeat step 7 two additional times
9. For trial three, repeat steps 3-5 with an end-expiratory pressure of 50 cmH₂O for 30 seconds (measured with a stop watch) and record the data on a flow sheet
10. Repeat step 9 two additional times
11. For trial four, repeat steps 3-5 with an end-expiratory pressure of 50 cmH₂O for 40 seconds (measured with a stop watch) and record the data on a flow sheet
12. Repeat step 11 two additional times
13. All data collection was inputted into MS Excel program for calculation of mean, median, standard deviation and other statistics. Graphs were created using MS PowerPoint.

RESULTS

Statistical analyze was performed to determine which recruitment maneuver involving end-expiratory pressures of 40-50cmH₂O for 30-40 seconds would improve static lung compliance using a preserved pig lungs while attached to a mechanical ventilator.

Using an Excel spreadsheet, volume, plateau pressure and PEEP were used to calculate static compliance and percent of change at each pressure level and time frame. A baseline trial was performed before each trial to determine the change in compliance after the maneuver.

RAW DATA

<table>
<thead>
<tr>
<th>Pressure of 40cmH₂O for 30 seconds</th>
<th>Ventilator Parameters</th>
<th>Baseline T1</th>
<th>Trial #1</th>
<th>Baseline T2</th>
<th>Trial #2</th>
<th>Baseline T3</th>
<th>Trial #3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pplat (cmH₂O)</td>
<td>14</td>
<td>17</td>
<td>13</td>
<td>15</td>
<td>13</td>
<td>17</td>
<td></td>
</tr>
<tr>
<td>PEEP (cmH₂O)</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Vte (ml)</td>
<td>221</td>
<td>764</td>
<td>223</td>
<td>771</td>
<td>231</td>
<td>768</td>
<td></td>
</tr>
</tbody>
</table>
The range for the mean static compliance (n=4) for all pressure and time trials was 19.0735 mL /cmH2O (range 49.18-68.26 mL/cmH2O) while the median was 59.59 mL/cmH2O.
VARIATIONS BETWEEN THE INDIVIDUAL TRIALS.

In the 40/30 trials, the mean (n=3) static compliance was 68.26 mL/cmH₂O (SD 7.661). In the 40/40 trials the mean (n=3) static compliance was 60.13888889 mL/cmH₂O (SD 4.24127645). In the 50/30 the trials the mean (n=3) static compliance was 49.18205128 mL/cmH₂O (SD 14.54963009). In the 50/40 trials the mean (n=3) static compliance was 59.03896104 mL/cmH₂O (SD 15.37933791).

The mean percent change of static compliance for 40/30 rose 151.8819188 %. The percent change for 40/40 was 209.3621399 %. The percent change for 50/30 rose 87.78159603 %. The percent change (n=2) for 50/40 was 153.9354839 %.

DISCUSSION

Research results did not support our hypothesis that the highest pressure for the longest time (50/40) would be the most effective method of sustained inflation (SI). All the trials rendered clinically significant findings for increasing static compliance. However, based on the percent change, the more moderate level of recruitment (40/40) trial was the most effective at recruiting lung alveoli and the 50/30 was the least effective.

The rise in static compliance was not consistent between each individual trial. We could not assign a cause to this variability. The mean baseline static compliance of the deflated lung ranged between 19.44 mL/cmH₂O and 27.1 mL/cmH₂O. This small range implies that deflation of the lung was fairly consistent even though the method used to press the lungs flat was fairly crude. At some point after trial three and what would have been trial four, the right lung ruptured leaving a hole that was more than an inch long. A second set of trials were not able to be performed because the ventilator auto-cycled and would no longer sustain pressure.

This study had numerous limitations due to the fact that there was only one pair of lungs. One limitation was that the lungs were preserved and did not react as living lungs would. Another limitation was that there were only one day of experimenting due to the lung rupturing, and then not holding pressure. Lastly, our baseline compliance was based on preserved lungs that were manually compressed, not lungs with a severe disease process such as ARDS.

There are many recommendations for future studies to improve the research base for recruitment maneuvers. A major improvement would be to include human subjects with acute restrictive disorders to see if there was a difference in results. It is also recommended that a greater number of participants be involved to see if the findings would be consistent. A repeat bench study with more sets of trials would also be a necessity to verify the effectiveness and safety of the procedure.

The study by Badet et al., which enrolled human participants (n=12) with early ALI/ARDS, who were
subjected to sustained inflation of 40 cmH.O for 30 seconds which was followed by setting the PEEP at 24 cmH.O and reducing it stepwise (Badet, Bayle, Richard, & Guérin, 2009). They found optimal PEEP level was found to be 12 ± 4 cmH.O.

In Kacmarek and Kallet’s review of existing literature, they were not able to determine the specific PEEP required to sustain a recruited lung (Kacmarek & Kallet, 2007). However, they do state that in order for a recruitment maneuver to be successful it must be immediately followed by appropriate PEEP. In Khier’s et al. study, they compared sustained inflation on pediatric patients to a staircase maneuver (Kheir & et al., 2013). In their study, after sustained inflation, the PEEP was set 2 cmH.O above the lower inflection point which they identified. This study did not identify a lower inflection point.

CONCLUSION

The main finding of this study implies that a single sustained inflation level may never be identified as the “best”. Just as with experience with PEEP studies demonstrates that there is no single “best” PEEP, our study seems to convey the idea that RCP’s will have to experiment with these techniques, and reevaluate the results frequently to protect their patients. As with ARDS patients, PEEP levels are typically the most effective at 20 cmH.O or less, but can be exceeded to improve lung compliance or optimize alveolar recruitment (Heuer, Kacmarek, & Stoller, 2013). After concluding this clinical trial, the question that arose was whether the results would be consistent if future studies were conducted using two different recruitment maneuvers.
REFERENCES


Kacmarek, R., & Kallet, R. (2007). Should recruitment maneuvers be used in the management of ALI and ARDS?. *Respiratory Care, 52*(5), 622-635

COULD ADDING PEEP DURING EXTUBATION, DECREASE THE AMOUNT OF SECRETIONS THAT FALL INTO THE LOWER AIRWAY AFTER CUFF DEFLATION?

Sonya Cappel C.S.T., SR.T.,
Sopha Cheam S.R.T.,
Yolanda Contreras B.S., C.PhT., S.R.T.,
Vanessa Underwood-Gonzalez S.R.T.

ABSTRACT

INTRODUCTION: The purpose of this study is to examine the effect of using positive end-expiratory pressure (PEEP) to prevent secretions from leaking below the deflated endotracheal tube cuff during extubation. OBJECTIVE: Apply various levels of positive end-expiratory pressure (4, 9, 14, 19 cmH₂O) and measure the volume of “mock secretions” that fall below the cuff post-extubation. METHODS: Using a mock oral cavity, the mock trachea was intubated, the cuff was inflated to recommended level, and attached to BiPap IPAP 20 cmH₂O rate 15 BPM. Application of the positive end-expiratory pressure was done in increments (EPAP 4, 9, 14 and 19). Both thin and thick mock secretions were introduced into the oral cavity, above the inflated cuff and observed for two minutes. The mock oral cavity was suctioned for 15 seconds prior to extubation and the volume of secretions falling below the cuff post-extubation was measured and recorded. This was repeated for each level of positive end-expiratory pressure. RESULTS: At positive end-expiratory pressure of 4 cmH₂O, 28.33 mL of secretions leaked below the cuff. At positive end-expiratory pressure of 9 cmH₂O, 27 mL of secretions leaked below the cuff. At positive end-expiratory pressure of 14 cmH₂O, 26.66 mL of secretions leaked below the cuff. At positive end-expiratory pressure of 19 cmH₂O, 24.33 mL of secretions leaked below the cuff. CONCLUSION: The use of high PEEP levels plays a major role in reducing the volume of secretions falling below the cuff and into the lower airways.

BACKGROUND

The process of keeping the lower airways patent includes maintaining careful airway management and minimizing the risk of aspiration. Throughout the time that patients are intubated, oral secretions tend to gravitate toward the subglottic space above the endotracheal tube cuff. This collection of secretions elevates the risk of aspiration that can induce infection of the lower pulmonary system (Armas, Coote, Guerra & Masila, 2013). Colonization of an acquired infection affects the respiratory function, and even the rate of reintubation (Armas, Coote, Guerra & Masila, 2013).

Invasive mechanical ventilation has the potential to allow microbes from the upper airways to drop to the lower airways. Ventilator-associated pneumonia (VAP) is an infection that affects relatively 15-20% of patients who are mechanically ventilated with positive pressure ventilation for at least 2 days. The inspiratory flow is
the driving force that moves the pathogens towards the lower airways and may play an important role in ventilator-associated pneumonia (VAP) pathogenesis (Sandrock, 2012).

Similarly intubated patients are susceptible to colonized secretions that can accumulate in the subglottic space above the endotracheal tube (ETT) cuff. Consequently during cuff deflation, there is an increased risk of secretion aspiration. However, suctioning of secretions before cuff deflation can capture secretions before they flow into the tracheobronchial tree. With the use of positive end-expiratory pressure (PEEP), a positive pressure gradient is achieved during cuff deflation, and the secretions may be pushed up from the subglottic space into the oropharynx, and away from the lungs (Hodd, Doyle, Carter, Albarran & Young, 2010). The same results might occur when a patient exhales or coughs (Hodd, Doyle, Carter, Albarran & Young, 2010).

How many oral secretions are removed during suctioning of the oral cavity? Is there residual volume left over? What prevents it from falling down below the cuff? The purpose of this study is to examine the effect that applied positive end-expiratory pressure (PEEP) has on preventing secretions from leaking past the endotracheal tube cuff. What level of positive end-expiratory pressure (PEEP) will best decrease aspiration of mock oral secretions? Positive end-expiratory pressure (PEEP) is frequently used during mechanical ventilation to increase the volume of gas left in the lungs at the end of expiration to prevent lung collapse and improve gas exchange. This study will evaluate whether positive end-expiratory pressure (PEEP) can be used as a tool to help prevent secretion aspiration during extubation.

Our hypothesis is that the level of PEEP will correlate negatively with the amount of secretions aspirated below the cuff. The highest level of PEEP used, 20 cmH2O, will result in the least volume of secretions aspirated into the lungs when performed before deflating the cuff and removing the endotracheal tube.

**METHODOLOGY**

**Measuring Devices**

**Philips Respironics V60**  
Respironics California, Inc.  
2271 Cosmos Court  
Carlsbad, CA 92011 USA  
1-800-345-6443

**Posey Cufflator #8199, SN 9310176**  
Posey Company  
5635 Peck Road  
Arcadia, CA 91006

**Exel Int. 10 ml. Disposable Syringe**  
llatex free  
REF 26265 (x5)  
Model 10 ml Leur Lock Tip Lot 070823  
Exelint International, Co.

**50 ml Measuring beaker**  
Kimax USA, No. 14000

**Equipment**

**Plastic measuring container** with lid  
(hole cut in center of lid approximately 1-1/4” diameter)  
Measure-Right Mixing Container  
1 Quart (946,35 ml)

**Partial cut vinyl tubing**  
1-1/4” OD x 1” ID

**Ozarka 16.9 fl.oz, plastic bottle** cut at bottom of label  
using top portion of bottle

**Duct Tape**  
Shurtech Brands  
32150 Just Imagine Dr, Avon, OH  
44011

**Endotracheal Tube, Cuffed, 9.0mm**  
Parker Flex-Tim PFHV, Parker Medical  
Ref. H-PFHV-70  
9457 S. University Blvd., PMB 331  
Highlands Ranch, CO 80126

**Ballard Trach Care T-Piece, 14Fr**  
Closed suction system for Adults  
Kimberly Clark, Ref 2205
Universal Bacteria Filter
AG Industries Bacteria Filters

Aspirator, Model No. 6260, 115V 60Hz
2.9A
Serial Number: 00002695
Date code: 0111
Contemporary Products, LLC
2055 South Main Street
Middleton, CT 06454-6151

Ozarka Natural Spring Water
Nestle Waters North America

900 Long Ridge Road
Stamford, CT 06902

Karo Syrup
ACH Food Companies, Inc.
7171 Goodlett Farms Parkway
Cordova, TN 38016

McCormick Assorted Food Color
McCormick & Co., Inc.
Hunt Valley, MD 21031

Ultra Clear Plastic Party Cup, 16 oz.
Item: 563562 Model: TP10-00090

Solo Cup Company
4444 W Ledbetter Dr.
Dallas, Texas 75236

Paper Towels
Great Value Brand Wal-Mart
Item No: 000439142
Walmart.com Customer Service
850 Cherry Avenue
San Bruno, CA 94066

Smartphone for stopwatch and camera, Galaxy 3S

VALIDATION OF MEASURING DEVICES

The Philips Resperonics V60 BiPAP was calibrated by running a self-test per the manufacturer guidelines. Verification of the aspirator was initiated by occluding the suction hose attached to the suction machine and observing if there was a change in pressure. A rise in pressure is an indication that there is no leak in the aspirator. If there is a leak present, make sure that all connections are on tight and run the verification process again. The pressure range should be between -100 to -120 cmH2O. The Posey Cufflator was validated by occluding the port at a high pressure of 120 cm H2O for 3 seconds. The pressure holds with no leak.

Suction Pressure
Validated: -120 cmH2O

Cufflator
Validation: 20 cmH2O

TESTING METHODS

Researchers 1 & 2 performed the experiment and Researcher 3 recorded the findings on the data flow-sheet. Researcher 4 photographed the process & assisted others as needed.

PREPARING ARTIFICIAL SECRECTIONS

1. Pour a mixture of purified water 60 mL: Karo Syrup 10 ml into a clear plastic cup.

2. Add 1 drop of food coloring into the cup & let color dissolve fully in the water.

3. Label the cup according to the designated PEEP value (4 cm H.O, 9 cm H.O, 14 cm H.O, 19 cm H.O).

4. Repeat steps 1-3 until there are 4 separate cups of colored water/syrup mixture.
SETTING UP THE EXPERIMENT

This experiment took approximately 45 minutes for initial set-up and approximately 15 minutes between each PEEP trial. The Mock oral cavity was wrapped with solid color tape so that researchers could not see the distal end of suction catheter while suctioning the mock upper airways.

1. Set BiPAP parameters as follows: S/T Mode, IPAP 20, Rate 15, I-Time 1.00, O2 21%, Rise 1, EPAP (PEEP 4, 9, 14, 19 cmH2O)
2. Attach mock trachea into the opening of the mock lung.
3. Insert 9.0 ETT into mock trachea stopping at 24 cm at the top rim of the mock oral cavity.
4. Inflate ETT cuff pressure using a 10 ml syringe. Verify cuff pressure using the Cuffalator (approximately 20 cmH2O).
5. Attach Ballard suction device to end of ETT tube and to end of connector of BiPAP.
6. Attach connecting tube between portable suction machine and Ballard port.

7. Set BiPAP parameters as follows: S/T Mode, IPAP 20, Rate 15, I-Time 1.00, O2 21%, Rise 1, EPAP (PEEP 4, 9, 14, 19 cmH2O)
8. Apply (EPAP) PEEP of 4 to start.

9. Measure 60 ml of water and 10 ml of Karo syrup (total solution 70 ml) mixture a clear plastic cup.
10. Add 1 drop of designated food coloring to mixture and mix well.
11. Label 4 clear plastic cups with different PEEP levels according to designated color
12. Pour water/syrup mixture from beaker into labeled plastic cups according to PEEP level.
13. Place 70ml of water/syrup mixture into the mock oral cavity above the inflated cuff of the ETT.
14. Start stopwatch/Smartphone™ for 2 minutes and observe the activity of the fluid.
15. Apply suction pressure of -120 cmH2O on portable aspirator.
16. Using the Yankauer, blind suction oral cavity for 15 seconds moving suction catheter back to back.
17. Disconnect collection bottle and record the amount of oral secretions suctioned.
18. Deflate cuff to extubate ETT from mock trachea.
19. Put BiPAP on stand-by.
20. Measure the remaining amount of secretions in the mock lung using measuring beaker.
21. Record results of the level of PEEP used and the amount of fluid collected on the flow sheet.

22. Wash ETT, Ballard suction device, and collection bottle, rinse well and wipe dry with paper towels.
23. Repeat experiment beginning with Steps 3-5.
24. Change (EPAP) PEEP level in Step 7 for next (EPAP) PEEP level.
25. Repeat Steps 12-19 for each (EPAP) PEEP level.
26. Record all results of each (EPAP) PEEP level.
27. Input all results into MSExcel program for calculations of mean, median, and standard deviation.
28. Creates graphics with MSExcel & MS PowerPoint

RESULTS

Secretions above the cuff were measured at different levels of EPAP (PEEP) (4, 9, 14, 19 cmH2O) using a mock lung and mock oral cavity with 9.0 endotracheal tube. The baseline trial was run using EPAP (PEEP) 4 cmH2O. Tables 1 through 3 identify the raw data collected.

<table>
<thead>
<tr>
<th>Suction Pressure</th>
<th>Cuff Pressure</th>
<th>Amount of Secretions</th>
<th>Volume Above Cuff (ml)</th>
<th>Volume Below Cuff (ml)</th>
</tr>
</thead>
<tbody>
<tr>
<td>-120 cmH20</td>
<td>20 cmH20</td>
<td>70 ml</td>
<td>42</td>
<td>28</td>
</tr>
<tr>
<td>-120 cmH21</td>
<td>21 cmH20</td>
<td>70 ml</td>
<td>48</td>
<td>22</td>
</tr>
<tr>
<td>-120 cmH22</td>
<td>22 cmH20</td>
<td>70 ml</td>
<td>50</td>
<td>20</td>
</tr>
<tr>
<td>-120 cmH23</td>
<td>23 cmH20</td>
<td>70 ml</td>
<td>55</td>
<td>15</td>
</tr>
</tbody>
</table>

Trial 1
The average (n=3) difference between the secretion above the cuff and below the cuff was 13.33333 mL with a PEEP of 4. The percent change between above and below was 47.05882%. The standard deviation of the secretions that fell below the cuff for PEEP 4 was (0.57735 mL).
See above. The average (n=3) difference between the secretions above the cuff and below the cuff was 16 mL with a PEEP of 9. The percent change between above and below was 59.25926%. The standard deviation of the secretions that fell below the cuff for PEEP 9 was (4.358899 mL).

See above. The average (n=3) difference between the secretions above the cuff and below the cuff was 16.66667 mL with the PEEP of 14. The percent change between above and below was 62.5%. The standard deviation of the secretions that fell below the cuff for PEEP 14 was (5.773508 mL).

The average (n=3) difference between the secretions above the cuff and below the cuff was 21.33333 mL with the PEEP of 19. The percent change between above and below was 87.67123%. The standard deviation of the secretions that fell below the cuff for PEEP 19 was (8.082904 mL).
The trials were run (n=3) for each level of EPAP (PEEP) using 70 mL volume of secretion mixture. The amount of secretions that leaked below the cuff post-extubation was recorded.

The percent change between PEEP 4 and PEEP 9 in the first trial was -21.4286 % and in second was 7.142857 %, while in the 3rd trial there was no difference in secretions.

The percent change between PEEP 9 and PEEP 14 in the first trial was -0.285714286 %, and in second was 0.071428571 %, while in the 3rd trial there was a decrease of 0.034482759 differences in secretions.

The percent change between PEEP 14 and PEEP 19 in the first trial was -0.464285714 %, and in second was 0.035714286 %, while in the 3rd trial there was no difference in secretions.

According to Figure 1, the average ml of secretions ranged from 24.3333333 mL to 28.3333333 ml of volume leaked below the cuff.

According to Figure 1, the average ml of secretions ranged from 24.3333333 mL to 28.3333333 ml of volume leaked below the cuff.

DISCUSSION

This research supported our hypothesis that increasing PEEP contributed to the reduction of secretions falling below the cuff of the deflated endotracheal tube (ETT) during extubation. At all levels of PEEP, one could see that the percent change between secretions above the cuff and below were clinically significant.

The significant difference between Trial 1 versus 2 and 3 was due to the use of the water/syrup mixture compared to the use of only water in Trial 2 and 3. A noticeable difference in the amount of secretions that fell below the cuff was recorded in the first trial compared to the second and third trial.

The average amount of secretions that fell below the cuff decreased significantly between PEEP 4 and 19; however, PEEP 9 and 14 resulted in little to no change.

In a related study by Armas et al, the correlation between the PEEP levels and the volume of secretions were comparable to our research findings (Armas, Coote, Guerra & Masila, 2013). Two important differences between the studies were that a bag-mask method was used for manual ventilation with applied PEEP and extubation was not included. Rather, their research study instilled secretions and left them for 60 seconds before measuring the volume of secretions that dripped through. In addition, the Armas et al, study did not create a mock oral cavity so they did not suction above the cuff prior to measuring the secretions that fell below the cuff.
According to the Hodd study, similar results were produced whereby the researchers used a PEEP of 35 in an open suction technique. The secretion volumes below the cuff post-extubation were inversely related to the PEEP level applied (Hodd, Doyle, Carter, Albarran & Young, 2010).

Various bacterial pathogens colonize in the lower respiratory tract which contributes to pulmonary infections (Bent & Toschlog, 2012). The primary objective of our study was to support our hypothesis that applying PEEP decreases the amount of secretions that fall below the cuff; therefore, helping to prevent the development of ventilator associated pneumonia (VAP).

There were many limitations to this research study. Initially, the mock trachea was made out of a thick plastic material, which created a rigid structure in comparison to the human trachea. In future trials we recommend using a more pliable material or preferably a human or animal cadaver for a more realistic outcome.

The characteristics of human secretions may affect its ability to go past the inflated cuff, this study created mock secretions. Perhaps a future study would use actual human secretions.

The use of a portable suction machine was another limitation. The suction machine did not have the same effect as a “wall suction” device because the initial pressure was not maintained throughout suctioning. The initial pressure was noted at -120 cmH₂O, however, during suctioning of secretions, pressures at the monometer of the portable suction machine periodically dropped as low as -80 cmH₂O.

The experiment used a BiPAP machine instead of a mechanical ventilator and the lowest PEEP level available on the BiPAP was PEEP 4. In a prior study, the research team used a manual PEEP device which the lowest level of PEEP began at zero. (Armas, Coote, Guerra, Masila 2013).

Additionally, the pressure was lost due to the BiPAP circuit having an exhalation port that could not be occluded due to the fact that a BiPap machine maintains PEEP in the face of this leak and due to the fact that the blower of the BiPap machine keeps the pressure up with a extremely high flowrate—which may or may not be an issue. In using a mechanical ventilator, the circuit is closed which maintains a constant pressure. It is suggested that another group of researchers could use a pressure-controlled mode with an invasive positive pressure ventilator to see if there might or might not be differences.

Researching the effects of using a higher PEEP level just prior to extubation could help minimize the amount of secretions falling below the cuff. In another study, the resulting secretions that were prevented from falling below the cuff, reinforced the idea that adding PEEP should be beneficial to the patient; therefore it is a suitable technique of choice prior to extubation. (Hodd, Doyle, Carter, Albarran & Young, 2010).

CONCLUSION

Minimizing the amount of secretions falling below the cuff during extubation was achieved by using a high level of positive end-expiratory pressure. In conclusion, the use of high PEEP levels and the amount of secretions play a major role in reducing secretions from falling below the cuff and into the lower airways.

A few questions that arise from the study: What is the highest level of PEEP that one can apply without causing a pneumothorax or depressed cardiac output? How long should the high level of PEEP be applied prior to extubating? Would there be a difference in the results if an invasive mechanical ventilator was used? A clinical study should be performed to explore the use of high PEEP during extubation to keep the lung clear.
REFERENCES


EFFECTS OF CLOSED SUCTIONING ON THE PRESSURES AT THE DISTAL END OF ENDOTRACHEAL TUBE

Vanessa Chairez, MA, SRT
Rochelle Harris, AA, SRT
Jo Ann Jove, AS, SRT
Melissa Phillips, SRT

ABSTRACT

INTRODUCTION: During closed suctioning, the generation of negative airway pressure and consequent lung volume loss can possibly alter positive end expiratory pressures (PEEP) delivered by the BiPap. OBJECTIVE: In our research, our goal is to investigate if closed suctioning maintains a stable airway pressure distal to the endotracheal tube (ETT). METHODS: We evaluated airway pressure by creating an intubated mock lung from a sealed glass jar attached to a manometer that measures the actual positive end expiratory pressure (PEEP) at the distal end of the endotracheal tube (ETT), and used a BiPap machine (set at 16.1/5 cm H\textsubscript{2}O) to generate positive end expiratory pressure (PEEP) in the airway. During suctioning, we continuously monitored the pressure at the distal end of the endotracheal tube (ETT), the pressure readings on the aspirator, and the positive end expiratory pressure (EPAP) levels on the BiPap machine. Suctioning was performed for 15 seconds, and was performed six times by two different people, for a total of twelve advances of the suction catheter. RESULTS: The experiment findings showed that EPAP levels read at the BiPap circuit were not significantly altered by suctioning, with or without secretions. At the distal end of the endotracheal tube (ETT) when secretions were present the PEEP dropped 3.1833 cm H\textsubscript{2}O; without secretions the PEEP levels dropped 8.2667 cm H\textsubscript{2}O. CONCLUSION: Suctioning an airway with the closed suction system may not change PEEP levels at the BiPap machine, but does change the PEEP levels distal to the endotracheal tube (ETT). This can be misleading because monitoring the ventilator we will see the EPAP levels unchanged, when in fact the actual PEEP was lost in the distal airways, possibly causing atelectasis.

BACKGROUND

Critically ill patients that have suffered acute respiratory distress syndrome (ARDS) or are unable to protect their airway are intubated with an artificial airway and placed on mechanical ventilation to deliver oxygen and ventilation (Kacmarek, Stoller, Heuer, & Egan, 2013, p. 1053). During mechanical ventilation, patients have either an endotracheal tube (ETT) or a tracheostomy tube, which both require inline

LSC: Kingwood Journal of Undergraduate Research in Respiratory Care Vol 3 no 3 page 31
suctioning, also known as closed suctioning. The patient would require suctioning to keep the airway clear of secretions. Closed suctioning uses a catheter that is advanced within the inner diameter of the endotracheal tube (ETT) or tracheostomy tube for secretion removal. When the patient has an endotracheal tube (ETT) or a tracheostomy, it is a site of bacterial growth that is encased in a biofilm. If the respiratory care practitioner does not perform the inline suctioning the biofilm has a greater risk of sliding down farther into the airways of the patient resulting in ventilator associated pneumonia (VAP) (Kacmarek, et al, 2013, pp. 1082-1083). The use of the closed suction technique on ventilator patients can decrease the likelihood of hypoxemia, especially in neonates and adults requiring high FiO2 or PEEP, or both, or at risk for lung derecruitment (Kacmarek, et al, 2013, p. 737).

The American Association of Respiratory Care (AARC) guidelines recommend pre-oxygenation with 100% oxygen for at least 30 seconds prior to suctioning; universal precautions such as personal protective equipment (PPE); duration of suctioning 10-15 seconds with catheter withdrawal and with the minimum negative pressure needed (less than or equal to 200 mmHg); and hyper oxygenation with 100% oxygen for 1 minute following suctioning (Seymour, 2009, p. 368).

Closed suctioning prevents hyperventilation and alveolar recruitment and hypoxemia (Caramez, et al., 2006, p. 498). However, the generation of negative airway pressure and consequent loss of lung volume can occur when the flow from the ventilator is lower than the suction flow (Masry, Williams, Chipman, Kratothbl, & Kacmarek, 2005, pp. 345-346). Endotracheal suctioning can cause derecruitment, which promotes collapse and the need to reopen lung units, thus potentially worsening lung injury in patients with acute respiratory distress syndrome (ARDS)/acute lung injury (ALI) (Caramez, et al., 2006, p. 498). Significant desaturation using closed-system suctioning has been reported in patients on intermittent mandatory ventilation who did not receive pre-oxygenation (Baun, 2002, p. 14).

Positive end expiratory pressure (PEEP) is the application and maintenance of pressure above atmospheric at the airway throughout the expiratory phase of positive pressure mechanical ventilation (Kacmarek, et al, 2013, p. 1360). Some believe that the inflation of alveoli increases diffusion of oxygen, which would prevent or treat hypoxemia (Caramez, et al., 2006, p. 498). In fact, treatment of hypoxic respiratory failure includes the use of positive end expiratory pressure (PEEP) so that the fraction of inspired oxygen (F.O2) can be decreased (Kacmarek, et al, 2013, p. 999).

During inline suctioning, do the patient’s lungs maintain the same PEEP? Studies have shown that during insertion of the catheter, the PEEP level may actually rise (Masry, et al, 2005, p. 346). In our research, our goal is to determine if closed suctioning maintains a stable airway pressure distal to the endotracheal tube (ETT). Will the PEEP be maintained in the distal “airways” of the mock lung during inline suctioning? We expect to see that closed suctioning will not change PEEP, and if it does, it will stay within 1 cm H.O.

**METHODOLOGY**

**Supplies:**

<table>
<thead>
<tr>
<th>Mason Jar</th>
<th>Stainless Scissors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jarden Home Brands</td>
<td>Office Depot</td>
</tr>
<tr>
<td>Daleville, IN</td>
<td>Boca Rotan, FL</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Ghostline Foam Board</th>
<th>Latex Free Hy-Tape</th>
</tr>
</thead>
<tbody>
<tr>
<td>CarolinaPad and paper</td>
<td>Hy-Tape International</td>
</tr>
<tr>
<td>Charlotte, NC</td>
<td>Patterson, NY</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th># 8 Endotracheal Tube</th>
<th>Digital Manometer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rusch Murphy</td>
<td>Respironics Inc.</td>
</tr>
<tr>
<td>Teleflex Medical Company</td>
<td></td>
</tr>
<tr>
<td>Research Triangle Park, NC</td>
<td></td>
</tr>
</tbody>
</table>
BiPap S/T-D was checked for leaks, and the approximate time of validation about 1 minute. Aspirator was turned on, and once connected, the suction hose was checked for patency by occluding the hose and watching the pressures rise. Approximate time of validation was about 5 minutes. Digital manometer was calibrated by scrolling the dial until the screen displayed 00.0 with no positive pressure. Approximate time of calibration is about 2 minutes.

**CALIBRATION OF TOOLS**

**ASSEMBLING MOCK LUNG**

The assembly of the mock lung should take approximately 30-45 minutes.

1. Trace around the inner lid of the mason jar on the foam board.
2. Then with the scissors, cut out the traced circle from the foam board.
3. With the latex tape, attach the distal end of the manometer line to the distal end of the uncuffed endotracheal tube.
4. Next, trace the circumference of the distal end of the endotracheal tube and digital manometer line together in the center of the precut foam board circle.
5. Cut a slit within the diameter of the traced circle so that you can slip the two tubes through the form board.
6. Secure the tubes on the proximal end of the foam board at the “8.0” marking on the endotracheal tube with the 3M Durapore tape.
7. Pour in the entire cup (approximately 103.5 ml) of Jell-O into the jar.
8. With the secured tubes in place, slip the outer lid of the mason jar over the tubes and twist cap on making an airtight seal.

**RESULTS**

<table>
<thead>
<tr>
<th>EPAP at the distal end of ETT in the mock lung</th>
<th>IPAP at the distal end of ETT in the mock lung</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Low Manometer Pressures (cm H₂O)</strong></td>
<td><strong>High Manometer Pressures (cm H₂O)</strong></td>
</tr>
<tr>
<td>Secretions</td>
<td>Secretions</td>
</tr>
<tr>
<td>No Secretions</td>
<td>No Secretions</td>
</tr>
<tr>
<td>0.8 - 4.1</td>
<td>17.1 - 16</td>
</tr>
<tr>
<td>Person A</td>
<td>Person A</td>
</tr>
<tr>
<td>2.6 - 4.1</td>
<td>17.3 - 18.1</td>
</tr>
<tr>
<td>0.8 - 2.2</td>
<td>18.1 - 18</td>
</tr>
<tr>
<td>2.8 - 0.7</td>
<td>17 - 13</td>
</tr>
<tr>
<td>Person B</td>
<td>Person B</td>
</tr>
<tr>
<td>2.4 - 3.8</td>
<td>17 - 13.2</td>
</tr>
<tr>
<td>1.5 - 4.7</td>
<td>18 - 13.5</td>
</tr>
</tbody>
</table>

*LSC: Kingwood Journal of Undergraduate Research in Respiratory Care Vol 3 no 3 page 34*
The average high manometer pressure read at the distal end of the ETT (IPAP) with secretions present in the suction catheter was 17.41667 cm H₂O (SD 0.4397703) and with no secretions the average high pressures were 15.3 cm H₂O (SD 2.181742423).

The average low manometer pressures (PEEP) at the distal end of the ETT with secretions were 1.816666667 cm H₂O (SD 0.825462833) and the average low manometer pressures (PEEP) without secretions were -3.266666667 cm H₂O (SD 1.381625452). With secretions present, the PEEP dropped from 5 cm H₂O to an average of 1.816667 cm H₂O which is a 63.6667 %Δ. Without secretions, the low manometer pressures (PEEP) dropped from 5 cm H₂O to -3.266666667 cm H₂O which is a %Δ - 165.333.

The percent change between high suction pressures with secretions and without secretions for person A were 0 %Δ and person B's mean percent change was 12.5 %Δ. The percent change between low suction pressures recorded during suctioning with secretions and without secretions at the distal end of the ETT for Person A showed a 1,900%Δ, while Person B had a 1400%Δ.

<table>
<thead>
<tr>
<th>Secretions vs. No Secretions</th>
<th>High Suction Pressures</th>
<th>Low Suction Pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Secretions</td>
<td>No Secretions</td>
</tr>
<tr>
<td>Person A</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-200</td>
<td>-200</td>
<td>0</td>
</tr>
<tr>
<td>-200</td>
<td>-200</td>
<td>0</td>
</tr>
<tr>
<td>-200</td>
<td>-200</td>
<td>0</td>
</tr>
<tr>
<td>Person B</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-225</td>
<td>-200</td>
<td>-25</td>
</tr>
<tr>
<td>-225</td>
<td>-200</td>
<td>-25</td>
</tr>
</tbody>
</table>

The average pressures between high and low manometer pressures recorded during suctioning with secretions at the distal end of the ETT for Person A showed an average 4765.385 %Δ, while Person B had an average 2215.476 %Δ between high and low pressures read at the manometer with secretions. Without secretions, the average high and low pressure recorded at the distal end of the ETT for Person A was -1949.89 %Δ and -3416.79 %Δ for Person B.
With EPAP of the BiPap machine set at 5 cm H.O, the measured mean EPAP during suctioning with secretions was 5.1 cm H.O and without secretions was 5.05 cm H.O. For the EPAP levels, each trial (n=6) was monitored and the number is recorded for every trial that was attempted by Person A and Person B. Each performed a trial (n=6) with secretions and no secretions. The suctioning had duration less than 15 seconds per attempt. The range of EPAP with secretions was a constant 5.1 of cm H.O and with no secretions was 4.9 cm H.O - 5.1 cm H.O (n=6). The median of EPAP with secretions and without secretions was a constant value of 5.1 cm H.O (n=6).

<table>
<thead>
<tr>
<th>MANOMETER PRESSURES</th>
<th>MANOMETER PRESSURES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hi Press</td>
<td>Low Press</td>
</tr>
<tr>
<td>Person A</td>
<td>18.1</td>
</tr>
<tr>
<td>Person A</td>
<td>18</td>
</tr>
<tr>
<td>Person B</td>
<td>13.2</td>
</tr>
<tr>
<td>Person B</td>
<td>13.5</td>
</tr>
</tbody>
</table>

### Set EPAP in cm H₂O on the BiPAP and Actual PEEP Read at the Distal End of the ETT without secretions

![Graph showing Set EPAP and Actual PEEP](image-url)

*LSC: Kingwood Journal of Undergraduate Research in Respiratory Care Vol 3 no 3 page 36*
We suggested that closed suctioning will not change PEEP levels during suctioning, and if it did, it will be less than 1 cm H₂O. This study does not support the hypothesis.

The experiment findings showed that PEEP levels read at the BiPap circuit were not significantly altered by suctioning, with or without secretions. When secretions were present, the PEEP levels did not change at all; without secretions the PEEP levels did change, but stayed within 1 cm H₂O.

The PEEP at the distal end of the ETT measured by the manometer in the mock lung changed drastically while suctioning both secretions and no secretions. When suctioning the airway with secretions, the actual PEEP dropped but maintained positive pressures at the distal end of the ETT. Whereas suctioning the airway without secretions reduced the actual PEEP at the distal end of the ETT to negative pressures.

The portable aspirator's suction pressures varied throughout the trials, never keeping the start pressure at exactly -200 mmHg. During suctioning, the pressures dropped anywhere from -100 mm Hg with secretions and to -5 without secretions. While the aspirator's pressures differed between operators, the distal pressures remained similar. The aspirator's pressures may have changed between operators because each person had their own technique of suctioning. Person A suctioned intermittently, while person B suctioned continuously. The vacuum was created by a portable suction machine which may not generate enough vacuum. It would be nice to repeat this study with “wall” suction to see if results would change.

While performing this study, there were a few limitations discovered. Variations in pressure changes in the aspirator between Person A and B, the study would benefit from additional trials with different people. Since the mock lung was essentially an intubated glass jar, it does not reflect compliance as a real lung would and the volumes were limited. Since the mock lung has smaller volumes, we cannot accurately compare the air that would be suctioned out from a real lung. This experiment should be repeated with a small volume cadaver lung and “wall” suction to better understand pressure changes during suctioning.

The mock lung has little or no airway resistance and the only airway resistance in the lung was the ETT. These factors would affect the pressures at the end of the ETT. “According to Poiseuilles Law, a decreased lumen leads to increased airway resistance. This would result in higher differentials between distal and proximal ends of the suction catheter (Wonser, Thompson, Bergeron & Erica, 2013).” Comparing to
their bench study above, they also concluded that suctioning levels should be altered based on the consistency of secretions (Wonser, Thompson, Bergeron & Erica, 2013).

In the study, “The Impact of Closed Endotracheal Suctioning Systems on Mechanical Ventilator Performance”, they used a 2-chamber training/test lung (Michigan Instruments, Grand Rapids Michigan) to stimulate a respiratory system (Masry et al, 2005, p. 346). Thus, studies have shown that during insertion of a 14 french catheter into an 8.0 mm inner diameter ETT, the PEEP level may actually rise (Masry et al, 2005, p. 346-347). In our research, we also used a 8.0 mm inner diameter ETT and a 14 french catheter and the PEEP levels in the glass jar (mock lung) fell with no secretions, which is opposite of the research above.

CONCLUSION

In conclusion, the AARC guidelines recommend that suctioning should be performed on an as needed basis as demonstrated by breath sounds (Seymour, 2009, p. 368). Our study confirmed that suctioning the airway without adequate secretions caused negative pressures in the airway distal to the ETT, which are more likely to cause atelectasis that can lead to hypoxemia. At this point, we can only recommend that we follow clearly established guidelines regarding suction as needed, rather than on an arbitrary schedule.

Would repeating this study on an actual patient using an ETT for high-frequency jet ventilation have similar results, i.e. lack of secretions would cause a larger pressure changes in the distal airways. On an actual patient the negative effects of wide pressure changes could be monitored by pulse oximetry and vital signs. Another study that might be interesting is comparing different sizes of ETT, because according to Poiseuilles’ Law, the diameter of the ETT has a direct impact on the airway resistance which could affect the distal and proximal pressures. On the other hand, the smaller inner diameter ETT will occlude easier by the suction catheter which would probably influence the pressure differential.
REFERENCE


Wonser, L., Thompson, M., Bergeron, T., & Erica, A. (2013). Bench study: Differences between proximal and distal pressures in a suction catheter during suctioning water when compared to mock thick secretions. *LSC Kingwood Journal of Undergraduate Research in Respiratory Care, 3*(2), 39-44.