Clinical Uses of the Open Lung Tool in Lung Recruitment

VENTILATOR WORKSHOP
203
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What is a Recruitment Maneuver?

- A Recruitment Maneuver is a procedure where a sustained positive pressure is applied, to an injured lung, over an increment of time, to recruit, open and keep open closed alveoli.
Why is Recruitment done?

- Recruitment maneuvers are performed to help improve oxygenation, help improve distribution of ventilation, and improve shunts.
- To try and determine the “Optimal PEEP” to keep the lung from dynamic collapse and alveolar de-recruitment.
- It is also done to re-recruit the lungs once there has been a break in the ventilation circuit.
Patient Selection

- Primarily on patients with ARDS/ALI
  - ARDS - (PaO2/FIO2 < 200) w/ bilateral infiltrates on x-ray.
  - ALI – (PaO2/FIO2 < 300)
- Patients in early phase ARDS, before the onset of fibro-proliferation.
- Ventilator Induced Lung Injury patients.
- Patients that are having trouble oxygenating due to the shunting caused by the injured lung.
Patient Selection

- Also in non-ARDS patients.
  - Patients with Alveolar Collapse.
  - Patients with Overnight turn lung status.
  - Patients with consistent Atelectasis.
Types of ARDS

- **Direct (Pulmonary/Primary)-Hard**
  - Effects lung parenchyma
    - Pneumonia
    - Aspiration
    - Lungs are primarily consolidated
    - Inhalation Injury
    - Lung Contusion
    - Near Drown

- **Indirect (Extra-Pulmonary/Secondary)**
  - Due to Acute Systemic Inflammatory Response
    - Sepsis
    - Trauma
    - Acute Pancreatitis
    - Alveolar collapse
    - Drug Overdose
Three Compartments of ARDS

1) Aerated normal lung susceptible to barotrauma induced by inappropriate ventilation. Usually located in the nondependent regions.

2) Areas that are collapsed due to interstitial infiltration and are potentially recruitable.

3) Airspaces that are filled with exudates and not recruitable lung. Usually in the dependant lung regions.
Adult ARDS
Spectrum of Regional Opening Pressures (Supine Position)

Superimposed Pressure

<table>
<thead>
<tr>
<th>Pressure Event</th>
<th>Opening Pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inflated</td>
<td>0</td>
</tr>
<tr>
<td>Small Airway Collapse</td>
<td>10-20 cmH₂O</td>
</tr>
<tr>
<td>Alveolar Collapse (Reabsorption)</td>
<td>20-60 cmH₂O</td>
</tr>
<tr>
<td>Consolidation</td>
<td>∞</td>
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</tbody>
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(from Gattinoni)

Lung Units at Risk for Tidal Opening & Closure
How Much Collapse Is Dangerous Depends on the Plateau

From Pelosi et al AJRCCM 2001
Lung Protective Strategy Patients

- ARDSNet Study
  - 6 ml/Kg IBW
  - RR up to 35 to maintain a pH > 7.30, then HCO3 if <7.15
  - Plateau Pressure < 30 cm H2O
  - Oxygenation Saturation 88 – 95%
  - PEEP/FIO2 Algorithm
    - FIO2: 0.3-0.4, 0.4-0.5, 0.5-0.7, 0.7-0.8, 0.9, 1.0
    - PEEP: 5, 8-10, 10-12, 12-14, 16-18, 20-24

- Reduces lung inflammation, improves oxygenation and gas distribution, prevents destruction of lung with repetitive opening and closing of the alveoli.

- But…most don’t follow the whole protocol!

- We have observed that Low Tidal Volume Ventilation...without sufficient amounts of PEEP....can cause alveolar de-recruitment.
Different Ways to Recruit the Lung

- Use of high CPAP for short periods of time. 40/40 rule
- Increased levels of PEEP - arbitrary
- Sustained inflation maneuvers
- Sigh breaths
- Optimal PEEP study
Pressure Control with PEEP

- Peak pressure of 45 cm H2O with a PEEP of 35 cm H2O for 1 minute.
- After the Recruitment, he applied either 5 cmH2O or 10 cmH2O to see which PEEP level created more stability for the previously collapsed alveoli.
- 5 cmH2O of PEEP showed significant instability and the 10 cmH2O of PEEP were stable.
- Concluded that after Recruitment maneuvers, inadequate amounts of PEEP permits unstable alveoli and may result in ventilator-induced lung injury despite improved oxygenation.
Injured Alveoli w/ Insufficient Amounts of PEEP
Injured Alveoli w/ Sufficient Amounts of PEEP
PEEP Usage

- Study by A. Estaban. AJRCCM 2000;161: 1450-1458
- **PEEP usage in ICUs**
  - 31% of patients were on ZERO PEEP.
  - 47% were on 1-5 cmH2O
  - 18% were on 6-10 cmH2O
  - 3% were on 11-15 cmH2O
  - 0.2% were on greater than 15 cmH2O
How do you know it worked?

- Improvements in oxygenation.
  - A 20% change or greater in PaO2/FIO2
- Improvements in intrapulmonary shunting.
- Improvements in lung mechanics “Lung Compliance”.
- Greater Tidal Volume for same pressure in (PC).
- Same Tidal Volume at less pressure in (VC).
How do you know it worked?

- Lower Plateau Pressure for the same Vt after a RM has been applied.
- *Best after disconnection from ventilator or post suctioning.
- *Rapidly counters the prolonged drop in PaO2 post suction.
Potential Problems

- **Hemodynamic instability**
  - Increased Pleural pressures may adversely effect pulmonary vascular resistance and cardiac filling or performance.
  - Cardiac Output decreases more profoundly in patients with pneumonia.
    - Caution should be used.
    - Decrease in Oxygenation

- **Cardiac arrhythmias**
- **Pneumothorax**
- **Regional Alveolar Overdistention**
- Ideal patient is deeply sedated or paralyzed.
- Not indicated for awake patients.
Clinical Objectives

- Optimize Gas Exchange and Oxygenation with a careful monitoring of airway pressure and its effect on blood circulation
- Preserve the healthy lung healthy
- Prevent the ventilator induced lung injuries
- Minimize time on ventilator
Clinical Application

- The Open Lung Concept®
  - Find the opening pressure
  - Find the closing pressure
  - Reopen the lung
  - Keep the lung open
- Sequential setting/reading of the SV 300 according to protocol
- Stepwise increase of Pressure Control level until opening pressure is found, indicated by corresponding decrease in dynamic compliance
- Stepwise decrease of PEEP until closing pressure is found, indicated by corresponding decrease in dynamic compliance
Prior to the Procedure

- The pt should be hemodynamically stable
- pt may have some sedation if agitated or has an increased RR
- Therapist must suction pt; calculate ideal body weight for target tidal volume; observe initial dynamic compliance and mean airway pressure (MAP); and adjust alarms.
Steps

- Increase PEEP gradually to 20cmH2O
- Increase PC to 30 cmH2O (PIP of 50cmH2O) -hold for 2 min
- Decrease PC to target tidal volume
- Decrease PEEP to closing critical pressure- add 2cmH2O to that pressure for optimal PEEP
- Re-recruit the lung by returning the PIP to 50 cmH2O -hold for 2 min
- Decrease PC to achieve the target tidal volume
LRM Protocol

- **PURPOSE:**
  - To provide safety and effectiveness guidelines for the use of the Open Lung Tool, to optimize ventilation by recruiting alveoli with lung recruitment maneuvers, to establish an alveolar closing pressure, to re-open the lung, and to keep the lung open. The Open Lung Tool protocol is a lung recruitment and best PEEP protocol.

- **SUPPORTIVE DATA:**
  - A sustained increase in airway pressure, can open collapsed alveoli. Combined with the addition of sufficient PEEP, to keep and maintain the alveoli open, the Lung Recruitment maneuvers may improve outcomes in patients with ARDS. The Open Lung Tool, combined with Lung Protective Ventilation Strategies, prevents destruction of the lung due to repetitive opening and closing of alveoli, reduces lung inflammation, and improves gas distribution and oxygenation.

- **POLICY:**
  - The Open Lung Tool will be utilized by trained Respiratory Care Practitioners who have demonstrated competency. Upon physician order, the Respiratory Care Practitioners will strictly follow the procedure listed below.

- **PROCEDURE:**
  - Verify all orders for therapy on the physician order sheet of the patient’s medical record.
  - Check the patient's identification bracelet.
  - A chest tube tray should be available.
  - Obtain baseline ABG, if there has not been an ABG in the last 8 hours, note pre-therapy hemodynamic values, verify with nursing staff that patient has stable values before performing this procedure, and address any ICP issues at this time.
LRM Protocol

- Calculate patient Ideal Body Weight using the following formulas:
  - Male = 50 + 2.3 [height (inches) - 60] or 50 + 0.91 [height (cm) - 152.4]
  - Female = 45.5 + 2.3 [height (inches) - 60] or 45.5 + 0.91 [height (cm) - 152.4]
- Calculate tidal volume for 6cc, 7cc and 8cc of Ideal Body Weight.
- Note PIP, Vt, Plateau pressure, EtCO2, Compliance, PEEP level and SpO2.
- Change the ventilation mode to Pressure Control. Avoid any other changes to the ventilator settings i.e. FiO2 unless absolutely necessary.
- Go to Open Lung Tool Screen, adjust the “Breath” count scale at the bottom right of the screen by pressing the (+) zoom key until the scale is 62 or 129 breaths.
- Simultaneously raise the PEEP, above closing pressure, by increasing PEEP gradually to 15 – 25 cm H2O, while decreasing the PC level at the same increments. Note:
  - Use PEEP levels 15-20 cm H2O for patients > 40 years of age that have preexisting lung conditions.
  - Use PEEP levels 20-25 cmH2O for patients < 40 years of age with no preexisting lung conditions.
- Raise the Pressure Control Level by increments of 5 cm H2O until a PIP of 40 cm H2O is reached. Hold that PIP for 2 minutes to recruit the lung. Note: At the lowest PEEP level of 15 cm H2O, the PIP may need to be greater than 40 cm H2O if a minimum Vt of 6cc per kg is not achieved, if Vt is not above 8cc/Kg, or if patient’s Plateau pressures are high. Never go above PIP of 60 cm.
- Maneuver should be stopped if patient becomes hemodynamically unstable.
Step 1: Change Mode to PC

- Change the ventilation mode to Pressure Control. Avoid any other changes to the ventilator settings i.e. FiO2 unless absolutely necessary.
- Go to Open Lung Tool Screen, adjust the “Breath” count scale at the bottom right of the screen by pressing the (+) zoom key until the scale is 62 or 129 breaths.
Step 2: Optimize PEEP

- Simultaneously raise the PEEP, above closing pressure, by increasing PEEP gradually to 15 – 25 cm H2O, while decreasing the PC level at the same increments. Note:
  - Use PEEP levels 15-20 cm H2O for patients > 40 years of age that have preexisting lung conditions.
  - Use PEEP levels 20-25 cmH2O for patients < 40 years of age with no preexisting lung conditions.
Step 3: Open the Lung

- Raise the Pressure Control Level by increments of 5 cm H2O until a PIP of 40 cm H2O is reached. Hold that PIP for 2 minutes to recruit the lung. Note: At the lowest PEEP level of 15 cm H2O, the PIP may need to be greater than 40 cm H2O if a minimum Vt of 6cc per kg is not achieved, if Vt is not above 8cc/Kg, or if patient’s Plateau pressures are high. Never go above PIP of 60 cm.
- Maneuver should be stopped if patient becomes hemodynamically unstable.
Step 4: Optimal VT

- Decrease PC level until a calculated tidal volume of 6 – 8 cc/kg is achieved. Wait 3 to 4 breaths per change until the calculated tidal volume is achieved.
Step 5: Find Lung Closing Pressure

- Decrease PEEP by 1 – 2 cm H2O, waiting 3 – 4 breaths per change, until alveolar collapse is noted. Alveolar collapse is recognized as a large decrease in tidal volume with a small decrease in pressure level, a large decrease in dynamic characteristic on the Cdyn wave form, or a downward spike in VtCO2. Use the cursor to note the PEEP level before collapse.
Step 6: Adjust PEEP

- Increase the PEEP to pre-lung collapse level, plus 2 – 4 cm H₂O.
Step 7:

- Increase PC level by increments of 5 until a PIP of 40 cm H2O is achieved and hold for 2 minutes to re-recruit the lung.
Step 8: Optimal VT

- Slowly decrease the PC level, waiting 3-4 breaths per change, until a calculated tidal volume of 6–8 cc/kg is achieved.
- At this point, you should see the same, or slightly higher, tidal volume at a lower ventilating pressure, and an improved lung compliance.
LRM Protocol

- Monitor the patient’s vital signs and ventilator function.
- Document on the Continuous Ventilation Record. Documentation should include pre and post PIP, PEEP, Plateau pressure, VtCo2, compliance, vital signs, SpO2 and any other pertinent hemodynamic values necessary.
- Switch patient back to original mode of ventilation and notify physician of the new PEEP level.
- Monitor patient ABG’s as needed.
- This procedure may need to be repeated anytime there is a loss of PEEP or a ventilator disconnection.
- Care should be taken to clamp the ET tube to prevent lung collapse. If the patient has a tracheostomy tube, a flex tube adapter will be added and clamped.
- A post procedure Chest X-ray, if indicated, may be obtained after the first Open Lung maneuver to verify that no pneumothorax has been caused.
8 step open lung picture

Step 1: Change to PC
Step 2: Optimize PEEP
Step 3: Open Lung
Step 4: Optimal VT
Step 5: Closing Pressure
Step 6: PEEP = 2-4 > CP
Step 7: Re-recruit the lung
Step 8: Optimal VT
John Doe Case Study
Day One

- 36 year old male involved in a Auto vs. Tree accident....The Tree won.
- JD was awake at the scene, developed decreased mental status, was intubated in the field, and airlifted to MC.
- JD arrived at MC Hypotensive 90/38mmHg, HR 127, difficult to obtained Pulse Ox, and Decreased BS in the Left Lung Fields.
John Doe Case Study
Day One

- X-ray obtained and showed a Right Main Stem Intubation, Left Atelectasis and lung volumes very low.
- ABG pH 7.008, pCO2 43, HCO3 10.3, sO2 78.9%, Base deficit of -19.6, Hb 8.6, Lactate level 8.6.
- ETT pulled back 3 cm.
- Ultrasound revealed free fluid in the abdomen.
- JD was transfused with packed cells, platelets.
- JD was 250lbs. (114 Kg), moderately obese.
John Doe Case Study
Day One

- JD was being treated for Hemorrhagic Shock, an Avulsion Fracture with Effusion, Blunt Head Injury, Abdominal Trauma, Acute Respiratory Distress, Orbital and Maxillary/Mandible fractures.
- JD went to surgery for a Transverse Colon resection, right Hemi-colonectomy, Ortho-surgery on his knee, an ICP monitor, and they delayed closing the granulating abdomen wound (packed open).
- Oh yea, they brought him out 15 liters positive!
- History revealed Opiate drug dependency...why the tree won.
John Doe Case Study
Day One

- JD was admitted to the Trauma ICU.
- Initial vent setting on the Servo i were: PRVC, RR-20, Vt-850, PEEP-7 and FiO2 100%.
- ABG: 7.39/25.2/142/15.2/98% on FiO2 100%
- HCO3 was given.
- Ventilator changed to RR-14, Vt-700, PEEP-5.
- We then settled in for the night trying to keep JD stable.
- The ICU RTs tried to be proactive and suggest vent changes based on the ABGs.
JD was stable for two days then the picture turned toward a ARDS type patient.

Trouble started around 0300. RT noticed that JD’s SpO2 dropped from 99% to 96%, the Compliance had dropped and PIP had gone up to 37 - 40 cmH2O. ABG revealed that JD’s pO2 went from 196 mmHg to 90 mmHg on the same FiO2 of 60 %.

The PEEP was raised to 7 cmH2O.

Later in the morning, an X-ray was ordered and showed “diminished lung volumes with increased densities in the Lingular area obscuring the Left Heart margin as well as in the Right Middle Lobe consistent with Atelectasis / PNA”.

JD’s abdomen was also enlarging and his ICPs were going up. The abdomen was decompressed but did not change the ventilation status. JD’s ICPs remained high.
John Doe Case Study
Day Three

- RTs & OLT to the Rescue!
- The respiratory staff saw this as a great chance to use the Open Lung Tool to show remarkable results!
- The patient needed lower pressures to protect his lungs, needed to keep his lungs open from collapse to avoid atelectasis, needed to find the “optimal PEEP” to help Oxygenation and needed instant results you could see.
Remember your “Categorizations of ARDS”. This falls into the “Indirect (Secondary or Extra-Pulmonary)” category because of Trauma, Alveolar Collapse, a Pancreatitis type “belly swell”, and the patient had transfusions.

We knew, therefore, that he would be easier to control.

“Indirects” are easier to see results on the ventilator graphics.

JD made for a perfect training candidate!

We must have had 15 people in the room to watch the maneuver!
Here we go!

RTs checked the orders, identified the patient, ensured a chest tube tray was available and got a baseline ABG.

As a practice, I have my RTs calculate the IBW for 6 ml/Kg, 7 ml/Kg, 8 ml/Kg.

Do not use the “room board weight”.

IBW:

Males: 50 + [ 2.3 X (height in inches-60) ]

Females: 45.4 + [ 2.3 X (height in inches-60) ]

RTs noted the PRE-PIP, Vt, Plateau pressure, VtCO2, Compliance, PEEP and SpO2 level.
Open Lung Tool On JD

- We started at a PEEP of 18 cmH2O and a PC of 22 mmHg (need to get above 8 ml/Kg)
- We watched the Compliance graphic.
- Our protocol is never to go above 60 cmH2O!
- We held this for Two Minutes!
- We then decreased the PC until we achieved a Tidal Volume of 6 ml/Kg.
- We then decreased the PEEP by increments of 1-2 cmH2O until we saw alveolar collapse.
- JD’s collapse happened at 10 cmH2O.
- We saw a decrease in Compliance, in VtCO2 and in Volume.
Since we just collapsed his lungs, we immediately put JD’s PEEP to 12 cmH2O and took the PC up to 28 mmHg to get a PIP of 40 cmH2O and held for 2 minutes.

We then decreased the PC until we achieved 6 ml/Kg. We switched JD back to PRVC and everyone went “WOW”.

JD’s Oxygenation status went from a pO2 of 90 mmHg to 239 mmHg.
JD’s PIP went from 37 cmH2O to 28 cmH2O.
JD’s Compliance went from 36 ml/cmH2O to 46 ml/cmH2O.
The Post-Open Lung Tool X-ray reading was “improved aeration in both lung fields compared to prior study” and the Trauma doctor’s note stated “there was dramatic improvement”.

JD had a second Open Lung Tool done seven hours later that day and the RTs were able to keep him progressing and decreasing his ventilator settings.

By the next day his ventilator setting were all back down.

Due to his injuries he went for a Tracheotomy.

He stayed in the hospital for a total of 11 days and then went to Trauma Rehab.
Recruitment Maneuver
...Started at 18 cmH2O PEEP

Started to decrease PEEP

Cursor put before collapse point PEEP at 10 cmH2O

Add 2-4 cmH2O... The new PEEP level

PC taken back up to open the lung.

The Cdyn went up as we increased PEEP and so did the VT CO2.

Point of collapse! Decrease in Cdyn, VT CO2; and VTe.
Case Study #1

- 53 year old female that came to Sutter Roseville Medical Center after a motor vehicle rollover. At the scene, she was conscious, anxious, and complaining of left sided chest pain. She went into a panic attack, her respiratory status continued to deteriorate, her blood pressure bottomed out, she went unconscious, and was intubated.
Case Study #1

- Her X-ray revealed focal densities on the right side and focal densities left lower lobes. Aeration of the right lower lobe appeared slightly worse. Left sided rib fractures were present. No Pneumothorax was noted. Diffuse air space disease, consistent with either edema, infection or contusion. Small right pleural effusion.
Case Study #1

- The Patient was on a FiO2 of 65% with a PaO2 of 200mmHg. Ventilator settings were within Low Volume Ventilation strategy ranges...but...Peep was at 5cmH2O.
- Over night, the patient’s oxygenation status deteriorated to a PaO2 of 48.1mmHg, on 100% FiO2, with a oxygen saturation of 84%.
- RT’s to the rescue. The MC staff knew that if we were able to get the Open Lung Protocol ordered that we could turn the patient.
- The protocol was ordered, the RTs used a base PEEP of 20 and PC of 20 cmH2O. The patient’s collapse point was found to be 9 cmH2O and the PEEP was raised to 11 cmH2O.
X-Ray after first Maneuver
Case Study #1

- The patient’s PaO2 went up to 239mmHg after the maneuver.
- The patient was easier to ventilate at a lower pressure.
- Along with a few more Open Lung Maneuvers, the patient’s contusion and left pleural effusion was resolving.
- The patient’s progress was dramatic and the patient was quickly weaned and extubated.
Case Study  #1
Case Study #2

- 19 year old female in a head on collision. She had lung contusions, a lacerated liver, lower extremity damage.
- Her PaO2 on her blood gas was 85mmHg on a FiO2 of 70% then dropped to 36.4mmHg on a FiO2 of 95%.
- This is what her initial X-Ray looked like.
Case Study #2
Patient needed to go through surgery first, so a low tidal volume strategy was used. Her PEEP was at 8 cmH2O and two chest tubes were inserted to drain fluid. After her first round of surgeries, the RTs asked for the Open Lung Protocol. Through daily OLT maneuvers the RTs were able to get her lung to this position.
Case Study #2
Case Study #2

- The patient was taken back to do her last surgery and this is what she came back like.
- Fluid over loaded with Atelectasis complements of Anesthesia.
Case Study #2

- The RTs knew that the Open Lung could reverse the patient and get her back in shape and after 3 maneuvers her was her X-Ray.
Case Study #2

- The RTs were very happy to see her turn and their confidence grew. They were now using the Protocol in the right patients at the right times and the breath to breath analysis recognition was allowing the RTs to do the procedure in a rapid and safe way.
Case Study #3

- 43 year old male that came in for fever and Pneumonia. Here was his initial X-Ray.
Case Study #3

- The patient was admitted to our floor for care and then went into respiratory distress. The next day, his x-ray looked like this.
Case Study #3

- The patient continued down the slippery slope and now looked like this.
- He got intubated and had high ventilating and plateau pressures.
Case Study #3

- The patient’s PaO2 was 47.9mmHg when the RTs finally got the OK to do the Open Lung Protocol. The Rt’s had been asking for a day and a half.
- The patient’s PaO2 went from 47.9mmHg to 148.0 mmHg with the first maneuver. The RTs identified the new PEEP setting and kept the patients lung open to improve oxygenation and to lower the ventilating pressures.
Case Study #3

- Here is the X-Ray after the Maneuver.
- This was followed by maneuvers every shift for 24 hours.
Case Study #3
What have we learned doing all our Open Lung Tool maneuvers?

- We have learned to get as many people involved with every OLT maneuver you do.
- We needed to review how long the maneuver was taking. Before 24 hours.
- If you have a really high Plateau Pressure you will not see the big “compliance change”. Look for the VT & VtCO2.
- If you have a high Plateau pressure you might have to go to 60 cmH2O to get about 8 ml/Kg!
- If you don’t have the OLT screen down to 62-129 breaths the RTs might go too high trying to see the change.
What have we learned doing all our Open Lung Tool maneuvers?

- Train the RTs to watch the Ventilator, the Patient and the Monitor! NO “deer in the head lights!”
- Teach your RTs that when you go too high on the PC, the Compliance graphic will go down not up. Do not keep going up on the PC to try to turn it the other way. In this case, you are so distended that there is no room for the lungs to expand which decreases compliance.
- This happens if you use the “room board weight” to calculate the IBW.
What have we learned doing all our Open Lung Tool maneuvers?

- In our Policy and Procedure, there is a note about where to start the PEEP levels: Use PEEP gradually to 15-20 cmH2O for patients >40 years of age that have preexisting lung conditions. Use PEEP levels 20-25 cmH2O for patients <40 years of age with no preexisting lung conditions.
- We now use this in all ICUs, and on ARDS and Non-ARDS patients.
- If doctors make changes in the middle, end the protocol and protect your RTs.
- Pick a Protocol and stick to it!
8 step open lung picture

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