

Esophageal Pressure Monitoring (EPM) (Respiratory Therapy)

Site Applicability

St. Paul's Hospital

Practice Level

Respiratory Therapists

Need to Know

Lung protective strategies used during mechanical ventilation should ideally provide sufficient transpulmonary pressure (airway pressure – pleural pressure) to maintain gas exchange while minimizing repetitive alveolar collapse, overdistention and volutrauma.

This is generally gauged by monitoring gas exchange via ABG and airway/plateau pressures. However, for this to be true, we are also assuming that chest wall compliance is normal, and as such has a minimal impact on overall respiratory system compliance.

In patients where chest wall compliance is reduced (i.e. obesity, ascites, bowel edema), elevated airway/plateau pressures may not accurately reflect alveolar overdistention. In these cases, a strict adherence to the aforementioned lung protective strategies may result in alveolar collapse, poor gas exchange, and ongoing ventilator induced lung injury.

Using an esophageal pressure measurement to estimate pleural pressure will allow for better estimation of transpulmonary pressures. In patients with reduced chest wall compliance, transpulmonary plateau pressure is a better reflection of alveolar distension, while transpulmonary PEEP is a better estimation of alveolar recruitment.

Equipment and Supplies

- For AVEA Ventilator:
 - SmartCath 8Fr Adult, Esophageal Pressure Monitoring Tube Set
 - SmartCath Extension, Esophageal Pressure Monitoring Tube Set
 - Water soluble lubricant
 - Magill forceps (optional)
 - Laryngoscope (optional)
- For Servo-U Ventilator:
 - Y Sensor Module
 - Getinge Y Sensor Module adaptor or equivalent (Luer lock tubing)
 - 3-way stop cock
 - Arterial line extension tubing
 - Luer compatible Esophageal Balloon

- 3 mL Syringe
- Blue pad
- Water Soluble Lubricant

Procedure

AVEA Ventilator

PREPARATION OF THE ESOPHAGEAL CATHETER AND VENTILATOR

A balloon test must be performed prior to placement of the esophageal balloon.

1. Connect the SmartCath esophageal extension tubing to the P_{es} port. Ensure the pins align properly with the P_{es} port.
2. Once connected, slide the sleeve of the extension tubing connector over the P_{es} port mount.
3. Connect the esophageal catheter to the extension tubing. Ensure the pins are aligned for a proper fit.
4. Once connected slide the sleeve of the catheter connector over the extension tube port mount.
5. Press **SCREENS** to access the Screens page.
6. Press **MANEUVERS** to access the Maneuvers page.
7. Press **ESOPHAGEAL** to access the Esophageal Maneuver Settings page.

NOTE: On the Esophageal screen, a message indicating the balloon status appears in the message bar. If **BALLOON DISCONNECTED** appears, reconnect the tubings.

8. A: If using 8 french catheter, Select **ADULT SIZE ESOPHAGEAL BALLOON** and press **ACCEPT**.
B: If using 16 french combo tube, Select Adult Size Nasogastric Esophageal Balloon and press accept.
9. The Balloon Test icon appears in the Maneuver Settings screen. Press **BALLOON TEST**.
10. The alert message **REMOVE BALLOON FROM PATIENT PRIOR TO LEAK TEST** appears. Press **CONTINUE**. The ventilator will now inflate and deflate twice to confirm the integrity.
11. Following this test, the message **ADULT BALLOON TEST PASSED** will appear in the message bar and a P_{es} software key becomes available.

NOTE: Pressing the P_{es} **OFF** key will inflate the esophageal balloon and the software indicator will change to P_{es} **ON**.

NOTE: Do **NOT** turn P_{es} **ON** until the catheter is in the patient and measurements are ready to be made.

PLACEMENT OF THE ESOPHAGEAL CATHETER:

1. Measure the distance from the tip of the **Nose (N)** via the **Earlobe (E)** to the **Xiphoid process (X)**. This is referred to as the **NEX** measurement.
NOTE: For oral insertion measure from the incisors instead of the nose.
2. Make note of the NEX measurement in centimeters and use that value to determine the insertion depth.

NOTE: A measurement of 40 cm (third hatch mark) will place the esophageal balloon in the lower $\frac{1}{3}$ of the esophagus for most adults. The distance between hatch marks on the catheter is 5 cm, with the first hatch mark located 30 cm from the catheter tip.

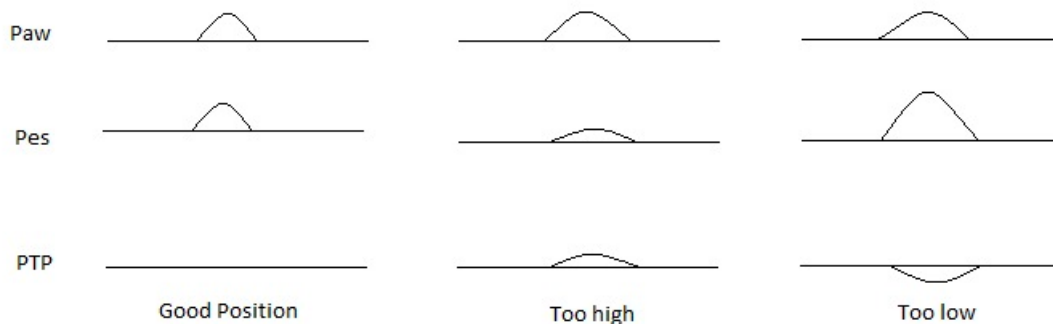
3. With the patient in a semi-Fowlers position, insert the catheter in short strokes 2 to 3 cm at a time. This will help to prevent coiling in the pharynx. The catheter should insert with minimal resistance. For oral insertion, try to follow the path of the endotracheal tube through the oral cavity.

NOTE: The RRT, RN, intensivist, fellow, or resident will be responsible for insertion of the esophageal balloon catheter.

4. Once the catheter has been inserted, access the Esophageal Maneuver Settings screen and turn **P_{es} ON**. The balloon will now be automatically inflated over a duration of 5 to 10 seconds.
5. Verify catheter placement by observing for cardiac oscillations on the P_{es} waveform, which will appear as a saw-tooth pattern.

NOTE: In the non-spontaneously breathing patient, both the P_{aw} and P_{es} should rise in the same direction with each mechanically delivered breath.

6. Placement verification via belly pump technique during expiratory hold.
 - Too high will show positive deflection at the Ptp
 - Too low (in the gut) will show negative deflection at the PTP
 - Good placement will show minimal deflection at PTP (no more than 1-2 cmH₂O) with a distinct cardiac oscillation
 - Balloon catheter in the lung will show minimal deflection at the PTP with a distinct lack of cardiac oscillation



NOTE: If the lungs are very non-compliant, the P_{es} scalar may need to be adjusted to visualize the cardiac oscillations.

7. Note the markings on the catheter and record the position in centimeters on Cerner (iView → Ventilation → Ventilator Adjuncts)
8. Final verification can be achieved with a chest x-ray. The NG combo tube has a distinct 1 cm radiopaque line at the distal tip and another at the distal end of balloon to help identify placement.

OBTAINING PRESSURE MEASUREMENTS:

Ensure patient is supine with HOB 30 degrees and confirm catheter is in the correct position prior to performing measurements.

1. Screen Display Setup:

Once the esophageal balloon has been inserted and correct position has been verified, set up the **MAIN SCREEN** as follows:

Waveforms Display:

- P_{aw} (cmH₂O)
- P_{es} (cmH₂O)
- P_{tp} (cmH₂O)

Monitored Values Display:

- P_{plat} (cmH₂O)
- P_{tp} Plat (cmH₂O)
- P_{tp} PEEP (cmH₂O)

2. Transpulmonary Plateau Pressure (P_{tp} Plat):

- a. Press and hold the **Inspiratory Hold** key.
- a. Press **Freeze** and scroll to the point where the inspiratory hold was performed or find value via **SCREENS → MONITOR**.

****Target P_{tp} Plat ≤ 25 cmH₂O (maintain low V_t strategy)****

3. Transpulmonary PEEP (P_{tp} PEEP):

- a. Press and hold the **Expiratory Hold** key.
- b. Press **Freeze** and scroll to the point where the expiratory hold was performed or find value via **SCREENS → MONITOR**.

****Target P_{tp} PEEP ≥ 0 cmH₂O****

or

****Set ventilator PEEP to target P_{tp} PEEP at the level below based on the FiO_2 ****

PLACING ESOPHAGEAL PRESSURE MONITORING IN STANDBY (for patient transport):

1. Access the Esophageal Maneuver Settings screen and turn **P_{es} OFF**. This will deflate the balloon.
2. Disconnect the SmartCath esophageal pressure monitoring catheter where it connects with the SmartCath extension tubing. *Do NOT disconnect the SmartCath extension tubing from the ventilator.* If the extension is disconnected from the AVEA, the balloon test will need to be repeated and the catheter will have to be removed from the patient.
3. After transport, reconnect the SmartCath esophageal pressure monitoring catheter to the extension tubing.
4. Access the Esophageal Maneuver Settings screen and turn **P_{es} ON** to resume monitoring.

SERVO-U Ventilator

PREPARATION OF SERVO-U VENTILATOR

1. Remove blank cartridge from Servo U.
2. Insert Y sensor module into newly freed up slot, note that grey cable is not required.
3. Ensure that Getinge Y sensor module adaptor or equivalent is attached to Y sensor module's nipple.
4. Servo U will automatically recognize and configure for EPM once module is inserted.
5. Attach arterial line extension tubing (84 inch) with 3-way stopcock.

PLACEMENT OF THE ESOPHAGEAL CATHETER

A. Cooper Medical Esophageal Balloon

Pre use check and patient measurement

1. Measure patient for NEX (nose/ear/xyphoid), target placement will be lower 1/3rd of esophagus with patient supine and HOB at 30 degrees. Average female will likely be 35 to 40 cm. Average Male will be 40 to 45cm depth of insertion.
2. Inflate Cooper balloon with 3 mL of air, ensure balloon is leak free. Withdraw the 3 mL of air once patency is confirmed.
3. Place blue pad or equivalent over patient's chest.
4. Lubricate balloon with water soluble lubricant.
5. Ensure no contra-indications exist
 - Esophageal varices
 - Esophageal trauma
 - Recent esophageal surgery
 - Coagulopathy
 - Platelets less than 80
 - INR more than 2
 - Post heart or lung transplant
 - Elevated intracranial pressure
6. Conventional insertion
 - i. With Y sensor module open to atmosphere ensure that Pes measures 0 cmh20.
 - ii. Consider freezing or soaking cooper catheter in ice bath to increase catheter rigidity.
 - iii. Ensure water soluble lubricant is present.
 - iv. Insert either nasally or orally, gently insert in 1 to 2 cm increments following hard palate.
 - v. Insert to target depth, attach 3-way stopcock and arterial line extension tubing to Y sensor module adaptor.
 - vi. Inflate cooper balloon with 1 mL of air, open 3-way stopcock to balloon and Y sensor.
 - vii. Verify cardiac oscillations present on Pes waveform.

Note: If difficult to see cardiac oscillations on current screen, press Maneuvers → Pes Catheter Positioning → start maneuver **without** a gentle chest compression. This will show a magnified Pes waveform that will be easier for confirming the presence of cardiac oscillations.

- viii. Check catheter positioning. Press Maneuvers → Pes Catheter Positioning → Follow Pes catheter position instructions and proceed to one gentle chest compression. This will verify the positive pressure occlusion ratio is within acceptable range of 0.8 to 1.2.
- ix. The Servo U is incapable of telling if the catheter is high or low, however a $\Delta\text{Pes}/\Delta\text{Paw}$ ratio of more than 1.2 indicates the balloon is too deep, a $\Delta\text{Pes}/\Delta\text{Paw}$ ratio of less than 0.8 indicates the balloon is sitting too high.

Optional

- i. If outside of range of 0.8 to 1.2 consider an expiratory hold with 1 to 3 gentle abdominal pumps with the record feature activated. A positive deflection on the PLe will indicate that the catheter is not deep enough. A negative deflection on the PLe indicates that the catheter is too deep. No or minimal deflection on the PLe with cardiac oscillations present indicates the correct position. No or minimal deflection with no cardiac oscillation has a very likely chance that catheter has been inserted into lung.
- ii. Adjust for depth as needed and repeat the Servo U catheter position maneuver to ensure proper placement.
- iii. Once placement is verified, measurements can be obtained. PLe, PLe, PL drive, Change Pes. The Servo U will continuously measure these measurements. Perform an Inspiratory Hold and Expiratory Hold to obtain true measurements, ensuring proper equilibration of pressures is transmitted to the ventilator.
- iv. Verify with abdominal X-ray, Cooper medical stainless steel guidewire should be visible on X-ray.
- v. Once verified with X-ray for positioning, remove the stainless steel guidewire, reattach the 3-way stopcock.
- vi. Never reinsert the stainless steel guidewire due to risk of perforation of catheter and patient tissues.
- vii. Document in Cerner the insertion procedure, depth of catheter, orifice of insertion, placement verification, and relevant pulmonary mechanics numbers.

7. NG-Guided Insertion Technique

- i. As the Cooper catheter tends to be very soft and floppy even with stainless steel guidewire, an alternate technique may be required.
- ii. For insertion, use a #18 French dual lumen NG, insert tip of Cooper catheter 1 cm into NG tube distal Murphy's Eye. Ensure lubrication is present.
- iii. Insert the NG with Cooper combination, NG will pull the Cooper down and into the patient.
- iv. Stop inserting at desired depth.
- v. Follow inflation and measurement techniques as described above.
- vi. If in desired place, firmly hold the Cooper Catheter, continue to insert the NG tube another 10 to 15 cm. Cooper catheter should disengage from NG.
- vii. Carefully withdraw the NG tube from patient.

8. Patient Transport with Cooper Medical Catheter

- i. Disconnect extension tubing from the 3-way stopcock.

B. *Flux Med Respiratory Mechanics Kit* → Pending

C. *Nutrivent Esophageal Balloon* → Pending

OBTAINING PRESSURE MEASUREMENT

The Servo U Y sensor module is “hot swappable” and can transfer from ventilator to ventilator for measuring assuming proper sanitation has been followed.

If balloon catheter is present, prior to measurement:

1. Verify depth of catheter; ensure patient is supine with HOB at 30 degrees.
2. Open 3-way stopcock to patient and atmosphere, use 3 mL syringe to withdraw all volume from balloon.
3. With 3-way stopcock open to atmosphere and no syringe attached, ensure Pes is at zero.
4. Using the 3 mL syringe, inflate balloon with 1 mL of air. Open 3-way stopcock to patient and Y sensor module, close to atmosphere.
5. Ensure cardiac oscillation present on Pes tracing.
6. To verify that catheter remains in correct position, press Maneuvers and follow the Servo U catheter positioning process as described above.

Note: If performing transpulmonary measurements, ensure correct catheter positioning by performing Pes Catheter Positioning maneuver prior to measurements in case balloon has moved.

Recommendations

- $P_{I\text{ ei}}$ (same as P_{tp} Plat) should be kept less than 20 to 25 cmH₂O
- $P_{I\text{ drive}}$ should be maintained less than 10 to 12 cmH₂O
- $P_{I\text{ ee}}$ (same as P_{tp} PEEP) should be in target range of 0 to 5 cmH₂O as per PEEP/FiO₂ table.

Documentation

1. Document in Cerner the position at which the esophageal catheter is secured. Check the position a minimum of once per shift and PRN.
2. Document transpulmonary pressures as follows:
 - a. For patients on mandatory modes of ventilation, document the following values in the Cerner with each monitoring and with every parameter change:
 - P_{tp} Plat
 - P_{tp} PEEP
 - P_{es}
 - b. The values for each of the parameters displayed on the AVEA screen should be the value documented UNLESS the waveform display indicates a value that is significantly different (greater than 3 to 5 cmH₂O). In these cases, determine the potential reasons for the discrepancy and document the rationale for which value is being used.
3. Document rationale for all changes made as per [B-00-12-12011](#) Ventilatory Monitoring Critical Care Protocol.

Definitions

Transpulmonary Plateau Pressure (Ptp Plat):

- $P_{tp\ Plat} = P_{plat} - P_{es}$
- where P_{es} = esophageal pressure
 - measured during inspiratory hold and estimates pleural pressure
- Target $P_{tp\ Plat} \leq 25 \text{ cmH}_2\text{O}$

Transpulmonary PEEP (Ptp PEEP):

- $P_{tp\ PEEP} = P_{EEPtotal} - P_{es}$
- where P_{es} = esophageal pressure
 - measured during expiratory hold and estimates pleural pressure
- Target $P_{tp\ PEEP} \geq 0 \text{ cmH}_2\text{O}$
 - see also Ptp PEEP-guided FiO_2 Table noted below

P_{tp} PEEP-guided FiO_2 Table

FiO_2	0.4	0.5	0.5	0.6	0.6	0.7	0.7	0.8	0.8	0.9	0.9	1.0
P _{tp} PEEP	0	0	2	2	4	4	6	6	8	8	10	10

References

1. Mauri T, Yoshida T, Bellani G, Goligher EC, Carteaux G, Rittayamai N, Mojoli F, Chiumello D, Piquilloud L, Grasso S, Jubran A. Esophageal and transpulmonary pressure in the clinical setting: meaning, usefulness and perspectives. *Intensive care medicine*. 2016 Sep;42(9):1360-73.
2. Piraino T, Cook DJ. Optimal PEEP guided by esophageal balloon manometry. *Respiratory care*. 2011 Apr 1;56(4):510-3.
3. Talmor, D et al. Mechanical ventilation guided by esophageal pressure in acute lung injury. *NEJM* 2008; 359: 2095-2104.
4. Talmor, D et al. Mechanical ventilation guided by esophageal pressure in acute lung injury/ARDS. *NEJM Journal Club*; Nov. 2008.
5. Talmor, D et al. Esophageal and transpulmonary pressures in acute respiratory failure. *Critical Care Medicine* 2006; 34: 1389-1394.
6. Gattinoni, L et al. Bench to bedside review: chest wall elastance in acute lung injury/acute respiratory distress syndrome patients. *Critical Care* 2004; 8: 350-355.

Initial Effective Date:	April 2010
Posted Date:	27-JAN-2022
Last Revised:	27-JAN-2022
Last Reviewed:	27-JAN-2022
Approved By:	PHC
	Respiratory Services
Owners:	PHC
	Respiratory Services