Tracheal pressure monitoring as a surrogate for esophageal pressure during Pressure Support Ventilation: a pilot study

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Introduction: Esophageal and transpulmonary pressure monitoring is invasive and expensive. Tracheal pressure monitoring may, to some extent, reflect changes in pleural cavity. We hypothesized that more simple and accessible tracheal pressure monitoring is feasible as a surrogate of esophageal pressure and can reflect work of breathing, lung stress, and respiratory muscle work.

Methods: In the observational cohort pilot study we included 59 MV patients (28 males) in SICU with PSV mode. We used monitoring of airway pressure (Paw), tracheal pressure (Ptr), esophageal (Pes) and transpulmonary (Ptp) pressure, plotted dynamic «tracheal pressure-volume» (Ptr-Vt) and «esophageal pressure-volume» (Pes-Vt) loops. We measured patient's work of breathing (WOBp), delta esophageal pressure (ΔPes), plateau pressure (Pplat), transpulmonary plateau pressure (Ptp plat), transpulmonary pressure at PEEP (Ptp PEEP), dynamic compliance of respiratory system (Cdyn), dynamic lung compliance (Clung dyn), dynamic chest wall compliance (Ccw dyn), delta transpulmonary pressure (ΔPtp=Ptp plat - Ptp PEEP), tracheal pressure at PEEP level (PEEPtr), minimal tracheal pressure during triggering (Ptrig tr). After that we plotted loops and estimated it's shape. We collected data at 6 steps: (1) at baseline PS and PEEP level (set by attending physician), (2) at PS+4 mbar level and baseline PEEP, (3) at PS-4 mbar level and baseline PEEP, (4) at PEEP+4 mbar level and baseline PS, (5) at PEEP set by end-expiratory transpulmonary pressure level (PEEPtp0) and baseline PS, and then (6) at PEEP-4 mbar level and baseline PS. In the subsequent pilot cohort study we included 48 MV patients (29 males) in SICU with PSV mode. We used monitoring Paw, Ptr and 'Ptr-time' curve shape, P0.1 at baseline PS level, and PS-4 mbar, PS-8 mbar, PS+4 mbar, and PS+8 mbar.

Results: We discovered 3 typical shapes of inspiratory part of **«tracheal pressure-time» (Ptr-t) curve**: triangle, square and S-shape. We found significant differences between different shapes of inspiratory part of «Ptr-t» curve in WOBp (p<0,0001), ΔPes (p<0,0001), PEEPtr-Ptrig tr (p<0,0001), and PS-ΔPtp (p=0,002) (**Fig 1A**). We found that WOBp can be estimated based on «Ptr-t» curve shape (**Fig 1B**). **Triangle-shaped** type of inspiratory part of «Ptr-t» curve (n=31) associated with «optimal» WOBp (0,20 (0,13-0,34)J/l), moderate ΔPes (5,0 (3,5-6,1)mbar), moderate PS-ΔPtp difference (-2,4 (-4,5-(-0,2)mbar), and moderate drop of the pressure during triggering (2,1 (1,5-2,5)mbar). **Square-shaped** type of inspiratory part of «Ptr-t» curve (n=8) associated with low WOBp (0,11 (0,09-0,15)mbar), moderate ΔPes (6,6 (4,7-6,9)mbar), moderate PS-ΔPtp difference (-2,0 (-4,8-2,8)mbar), and small drop of the pressure during triggering (1,8 (1,3-2,2)mbar). **S-shaped** type of inspiratory part of «Ptr-t» curve (n=17) had high WOBp (0,39 (0,26-0,73)J/l), high ΔPes (7,4 (6,2-11,7)mbar), high PS-ΔPtp difference (-5,6 (-10,8-(-4,1))mbar), and deep drop of the pressure during triggering (4,1 (3,0-4,8)mbar). PS and PEEP shift led to changes in these parameters according to the shape type of inspiratory part of «Ptr-t» curve.

We discovered 4 types of **dynamic «Ptr/Vt» loops**: inverted (n=41), classical (n=7), linear (n=7), and S-shaped (n=4). We found significant differences between different shapes of dynamic «Ptr/Vt» loops in ΔPtp (p=0,05) and Clung dyn (p=0,020), which allowed to estimate delta transpulmonary pressure (lung stress)(**Fig.1C**) without esophageal pressure monitoring. **Inverted**

dynamic «Ptr/Vt» loop associated with the less ΔPtp (13,6(11,4-18,2)mbar) and the biggest Clung dyn (32,7(26,2-45,3)мл/мбар), PEEP increase didn't led to alveolar recruitment (no drop in ΔPtp or increase of Clung dyn). **Classical** dynamic «Ptr/Vt» loop associated with moderate ΔPtp (16,5(16,0-19,0)mbar) and low Clung dyn (27,1(20,6-31,8)ml/mbar) - which can be a signs of more severe lung injury, PEEP increase led to increase of Clung dyn and decrease of ΔPtp (alveolar recruitment). **S-shaped and linear** «Ptr/Vt» loops associated with the lowest Clung dyn (23,8 (19,6-28,5)ml/mbar), and the highest ΔPtp (19,4 (16,5-22,2)mbar). We found significant differences in P0,1 at PS0 and PS-4 mbar steps in patients with different 'Ptr-time' shapes at baseline PS level ($p<0.05$) (**Fig 1D**).

Conclusion: Tracheal pressure monitoring may reflect WOB, lung stress, and neural respiratory drive in pressure support ventilation. Further studies are needed to reject or confirm this hypothesis.

Figure 1. Delta esophageal pressure, delta trigger pressure, and transpulmonary pressure in patients with different shapes of 'tracheal pressure-time' curve (A); Work of breathing in patients with different shapes of the 'tracheal pressure-time' curves at baseline PS (B); Delta transpulmonary pressure at different PEEP levels in patients with different shapes of dynamic 'tracheal pressure-volume' loops at baseline PS (C); P0.1 at different PEEP levels in patients with different shapes of 'Ptr-time' curve at baseline PS level (D).