

LETTER



# Airway closure and fiberoptic evidence of bronchial collapse during the acute respiratory distress syndrome

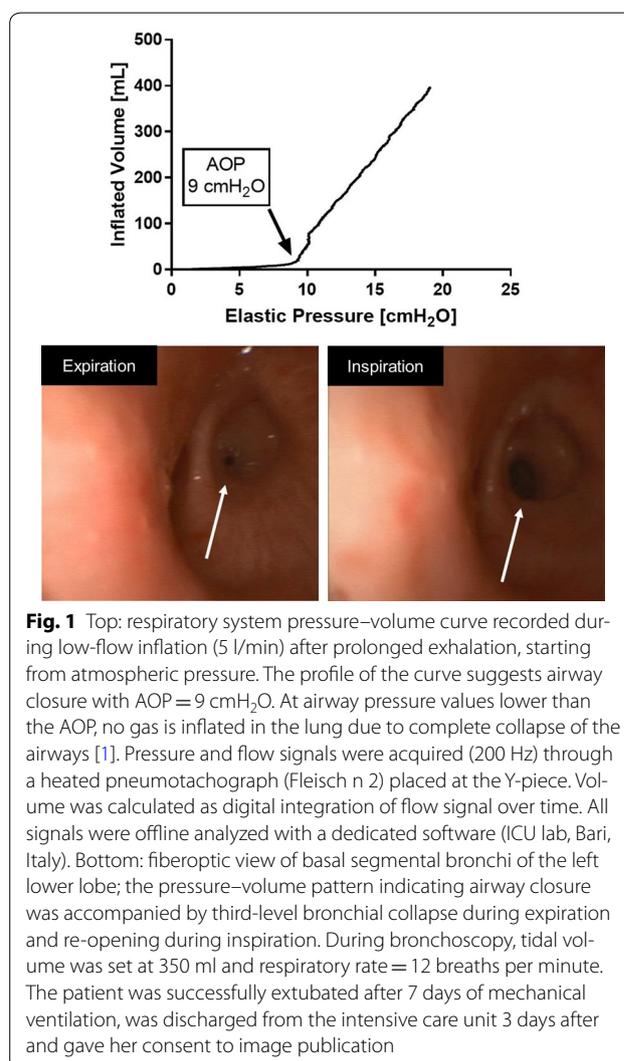
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Dear Editor,

Airway closure affects approximately one-third of patients with acute respiratory distress syndrome (ARDS) undergoing mechanical ventilation in the absence of spontaneous breathing [1, 2]. When this phenomenon is present, airways collapse during expiration; therefore, end-expiratory pressure at airway opening (although measured during an end-expiratory occlusion) is not equilibrated with alveolar pressure, and tidal inflation starts only when an airway opening pressure (AOP) is overcome. Airway closure leads to misinterpretation of static respiratory mechanics and makes actual end-expiratory alveolar pressure (and end-expiratory lung volume) independent from set PEEP, if this is lower than the AOP [3]. Moreover, airway opening and closing may yield bronchiolotrauma, which can contribute to lung injury [1, 4, 5].

The exact cause of airway closure is not known, but its occurrence seems related to surface tension modifications (i.e. gas–liquid interfacing) in terminal bronchioles favored by surfactant depletion, and to aeration loss causing functional residual capacity to decrease below a critical ‘closing volume’ of the airways [3, 6, 7]. Airway closure is diagnosed on the respiratory system pressure–volume (P–V) curve recorded during low-flow inflation, that shows a pronounced lower inflection point corresponding to AOP (Fig. 1, top). Although this phenomenon has



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been confirmed by electrical impedance tomography [8], the anatomical site where the airways collapse is not fully understood.

In June 2019, a 65-year-old woman (height 167 cm, body mass index 29 kg/m<sup>2</sup>) developed pneumonia-induced severe ARDS on day 4 after emergency surgery due to cancer abscess of the uterus. Under invasive mechanical ventilation, continuous sedation and paralysis (volume-controlled ventilation: tidal volume 400 ml, respiratory rate 20 breaths/min), she exhibited total PEEP = 5-cmH<sub>2</sub>O and plateau pressure 19 = cmH<sub>2</sub>O, with set PEEP = 0 cmH<sub>2</sub>O (Fig. E1). On the P–V curve, airway closure was diagnosed and AOP of 9 cmH<sub>2</sub>O identified (Fig. 1, top). Using fiberoptic bronchoscopy (performed with set PEEP = 0 cmH<sub>2</sub>O), we observed a relationship between the P–V curve pattern of airway closure and the evidence of third-order bronchial collapse (Fig. 1, bottom). This particular behavior was confirmed in other regions of the bronchial tree (Fig. E2), and we noticed that it was associated with the presence of mucus, which is consistent with gas–liquid interfacing being an important factor favoring airway collapse [9]. Coherently with airway closure pathophysiology, the phenomenon disappeared as PEEP was raised to overcome the AOP.

Although airway closure seems to mostly involve terminal bronchioles [6], these observations indicate that it may be associated to some degree of collapse also in upper bronchi. This suggests that inflammation and patient's individual characteristics may promote airway closure not only in the bronchioles, but also in more proximal regions of the bronchial tree [10].

#### Electronic supplementary material

The online version of this article (<https://doi.org/10.1007/s00134-019-05800-0>) contains supplementary material, which is available to authorized users.

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#### Compliance with ethical standards

#### Conflicts of interest

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#### References

- Chen L, Del Sorbo L, Grieco DL et al (2018) Airway closure in acute respiratory distress syndrome: an underestimated and misinterpreted phenomenon. *Am J Respir Crit Care Med* 197:132–136. <https://doi.org/10.1164/rccm.201702-0388LE>
- Yonis H, Mortaza S, Baboi L et al (2018) Expiratory flow limitation assessment in patients with acute respiratory distress syndrome. A reappraisal. *Am J Respir Crit Care Med* 198:131–134. <https://doi.org/10.1164/rccm.201711-2326LE>
- Grieco DL, Anzellotti GM, Russo A et al (2019) Airway closure during surgical pneumoperitoneum in obese patients. *Anesthesiology* 131:58–73. <https://doi.org/10.1097/ALN.0000000000002662>
- Chen L, Del Sorbo L, Fan E, Brochard L (2018) Reply to borges: the plausibility of "Bronchiolotrauma". *Am J Respir Crit Care Med* 197:1087–1088. <https://doi.org/10.1164/rccm.201710-2131LE>
- Muscledere JG, Mullen JB, Gan K, Slutsky AS (1994) Tidal ventilation at low airway pressures can augment lung injury. *Am J Respir Crit Care Med* 149:1327–1334. <https://doi.org/10.1164/ajrccm.149.5.8173774>
- Coudroy R, Lu C, Chen L et al (2019) Mechanism of airway closure in acute respiratory distress syndrome: a possible role of surfactant depletion. *Intensiv Care Med* 45:290–291. <https://doi.org/10.1007/s00134-018-5501-5>
- Grieco DL, Brochard L, Drouet A et al (2019) Intrathoracic airway closure impacts CO<sub>2</sub> signal and delivered ventilation during cardiopulmonary resuscitation. *Am J Respir Crit Care Med* 199:728–737. <https://doi.org/10.1164/rccm.201806-1111OC>
- Sun X-M, Chen G-Q, Zhou Y-M et al (2018) Airway closure could be confirmed by electrical impedance tomography. *Am J Respir Crit Care Med* 197:138–141. <https://doi.org/10.1164/rccm.201706-1155LE>
- Hubmayr RD (2002) Perspective on lung injury and recruitment: a skeptical look at the opening and collapse story. *Am J Respir Crit Care Med* 165:1647–1653. <https://doi.org/10.1164/rccm.2001080-01CP>
- Rainer WG, Mutz A, Kelble DL (1967) Bronchial collapse causing air trapping. *Am Rev Respir Dis* 96:802–804. <https://doi.org/10.1164/arrd.1967.96.4.802>