TITLE : COMPONENTS OF PEEP-INDUCED LUNG-THORAX VOLUME INCREASE

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Introduction. PEEP may improve oxygen exchange by increasing FRC. If unstable lung is recruited at end-inspiration, PEEP may prevent its collapse at end-expiration, and this volume increase would be complete within the first tidal breath after a step change in PEEP. This increase would be proportional to the total respiratory system compliance (C_{LT}). PEEP may also result in an additional increase in lung volume by overcoming forces which require a longer inflation time than the usual end-inspiratory pause. Thus, the full increase in FRC with PEEP would take several breaths and would be larger than that indicated by the C_{LT}. Our objective was to investigate the relative contributions of these two mechanisms.

Methods. 13 adult patients requiring mechanical ventilation for APF were studied. Each was ventilated at a constant rate ($F_IO_2$0.5 and V_T 13-15% predicted TLC). Airway and esophageal pressure, expired tidal volume (V_E), FRC, P_IO_2, PaO_2, and $PaCO_2$ were measured at increments of 5 cmH_2O of PEEP. Breath-by-breath expired tidal volume was measured after the application of 10 cmH_2O PEEP in nine patients, to determine the time dependency of the lung volume change. This was also examined when PEEP was applied after two hyperinflations. Calculations. 1) Total respiratory system compliance (C_{LT}), $V_E/\Delta Paw$, derived from the difference between a period of zero end-inspiratory flow of 1.2 seconds and end-expiration 2) FRC compliance (C_{FRC}) from $\Delta FRC/\Delta EEP$ 3) $P(A-a)O2_{0.5}$. The study was approved by the Human Research Committee and informed consent was obtained for each patient.

Results. The mean initial FRC (55% of predicted supine; range 26-101%) correlated with the initial C_{LT} (r=.82; P<.001). Figure 1, is a pressure-volume diagram of the mean LT data. The C_{FRC} increased with increments of PEEP. At each PEEP level the corresponding C_{FRC} is larger than the C_{LT}. These differences are significant at PEEP levels of 8 and 13 cmH_2O. Thus, at the same lung volume, there is a pressure difference between the end-inspiratory and end-expiratory data. Conversely, a volume difference exists between end-inspiration and end-expiration at the same pressure. The volume difference between the end-inspiratory and end-expiratory data maintained by PEEP at 18 cmH_2O, was computed for each patient. This correlated inversely with the associated improvement in $P(A-a)O_2$ (r=-.69;P<.05). The additional volume was 38±9% (SD) of the total FRC change. The relative contributions of the lung and chest wall to the observed LT changes were measured in ten patients. At iso-lung volume the pressure difference between the end-inspiratory and end-expiratory data was distributed across both the lung and chest wall with the lung component accounting for 0.63±.25 (SD) of the total LT changes. After a step change in EEP of 10 cmH_2O, 68±17% (SD) of the total FRC change was complete within the first breath and the volume retained by the patient on the first breath correlated directly with C_{LT} (r=.91;P<.001). Breath-by-breath V_E showed a 98% return to steady state in 4.4±3 (SD) breaths, (27±19 sec). Prior hyperinflation of the lung did not alter the findings.

Discussion. Three time-dependent factors may explain the observed volume changes 1) normal pressure-volume hysteresis 2) stress relaxation 3) recruitment of non-ventilated lung. These data do not permit quantitative discrimination between these factors. We conclude that both the prevention of collapse of unstable alveoli and time-dependent lung and chest wall factors are involved in the mechanism by which PEEP increases FRC and improves oxygen exchange. 98% of the time course of the induced volume change occurs in 2-60 sec. C_{LT} incompletely describes the elastic properties of the lung and its responses to PEEP.

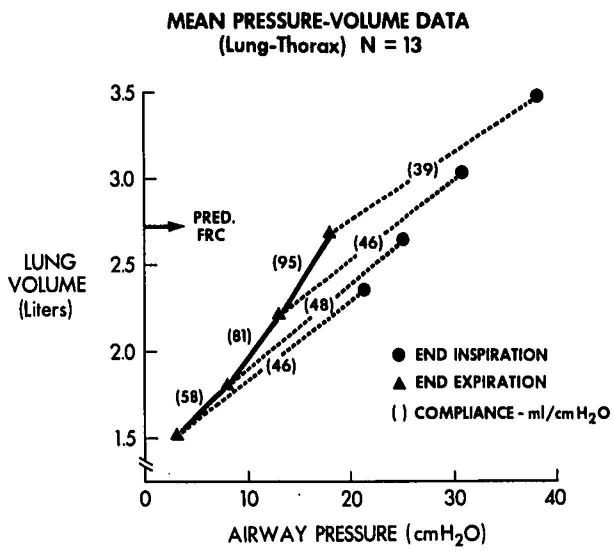

Figure 1

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