Comparative effects of variable ventilation and a stepwise recruitment maneuver on atelectasis and hemodynamics in an experimental model of ARDS

L. Vivona^{1,2}, A. Braune², T. Bluth², B. Stender³, R. Huhle², T. Koch², M. Gama De Abreu²

¹ Department of Neurosciences, Reproductive and Odontostomatological Sciences University of Naples "Federico II" - Naples (Italy);

² Department of Anesthesiology and Intensive Care Medicine, Pulmonary Engineering Group, University Hospital Carl Gustav Carus, Technische Universität Dresden - Dresden (Germany);

³ Drägerwerk AG & Co KGaA - Lübeck (Germany)

Background:

Variable volume controlled ventilation (VV) has the potential to reverse atelectasis. We hypothesized that VV is superior to a conventional stepwise recruitment maneuver (RM)

Methods

❖ 9 pigs (DD24-5131/354/64) were anesthetized and ventilated in airway pressure release ventilation (APRV) mode with positive end-expiratory pressure (PEEP) and driving pressure of 15 cmH₂O, as well as respiratory rate (RR)=20/min.
❖ Four saline lung lavages were performed.
❖ Lungs recruited in APRV by stepwise increase of PEEP to 45 cmH₂O (10 cmH₂O increments, RR=20/min, driving pressure=15 cmH₂O) (stepwise RM). Then, a decremental PEEP trial was conducted in volume-controlled ventilation with VT=6 mL/kg and RR=30/min to determine the PEEP that resulted in the highest compliance (optimal PEEP).
❖ Animals were submitted to two recruitment strategies (random sequence, crossover study):

- 1) stepwise RM followed by 30 min of volume-controlled ventilation with VT=6 mL/kg, RR=30/min and optimal PEEP;
- 2) VV, consisting of 30 min volume-controlled ventilation with random variation of VT (mean=6mL/kg, normal distribution, coefficient of variation of 30%), RR=30/min and optimal PEEP.

Figure 1 – Time course of interventions and measurements. PEEP, Positive End Expiratory Pressure; RM, Recruitment Maneuver; VCV, Volume Control Ventilation

Before recruitment strategies, animals were disconnected from the ventilator for 30 seconds and volume-controlled mechanical ventilation resumed during 5 minutes with constant VT=6 mL/kg, RR=30/min and optimal PEEP to reset lung history. I:E ratio and FIO₂ were kept constant at 1:1 and 1.0, respectively.

Before and after each recruitment strategy, lung aeration was assessed by computed tomography, and the center of aeration along the ventral-dorsal gradient was determined (Figure 2).

Results

- ❖ Both recruitment strategies increased the amount of normally aerated tissue, mainly in dorsal zones (Figure 5), and decreased the amount of poorly and non-aerated lung tissue (Figure 2 and Figure 3)
- ❖ More pronounced reduction of non-aerated lung tissue with VV than maxRM (Figure 3)
- ❖ The stepwise RM, but not VV, resulted in significant reduction of mean arterial (Figure 4) and increase of heart rate (111 [80...111] to 121 [106...131] bpm, P=0.004, median [1st ...3rd quartile])
- ❖ Shift of center of aeration in both groups along the ventro-dorsal gradient
- ❖ No influence of recruitment strategies on distribution of relative perfusion along the ventro-dorsal gradient (Figure 5)
- ❖ Improved PaO₂ and Compliance in both groups (Figure 6)

Conclusion

In this model of ARDS in pigs, VV more effectively reduced non-aerated lung tissue, with less effects on hemodynamics as compared to a stepwise RM.

Contact: vivonag@tiscali.it

Figure 2 – Distribution of ventilation compartments and pulmonary perfusion in an experimental animal

Figure 3 – Comparison of the ventilation compartments with significant decrease of the poorly aerated areas. *p<0.05 by T-test (Before vs. after intervention) (normally aerated: VV: P<0.001, maxRM: P<0.001; poorly aerated: VV: P=0.047, maxRM: P=0.002; non-aerated: VV: P<0.001; maxRM: P=0.001). ΔVV vs. Δ maxRM P=0.046 by two-way repeated measures ANOVA.

Figure 4: Minimal Mean Arterial Pressure (MAP) between VV and maxRM at PEEP = 45 cmH₂O (P<0.001) and VV and maxRM until 5 minutes after recruitment (P=0.035).

Figure 5 – Change of the center of perfusion and change of the center of aeration. Left side: center of perfusion *p<0.05 by T-Test (Before vs. after intervention), maxRM P=0.877; VV P=0.077. Right side: center of aeration *p<0.05 by T-Test (Before vs. after Intervention) maxRM P=0.006; VV P<0.001.

Figure 6 – Left side: PaO₂ *p<0.05 by T-test (Before vs. after intervention), maxRM: P<0.001; VV: P<0.001; ΔVV vs. ΔmaxRM: P=0.041. Right side: Compliance of respiratory system *p<0.05 by T-test (Before vs. after intervention), maxRM: P<0.001; VV: P<0.001 and ΔVV vs. ΔmaxRM: P=0.082.