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(Article begins on next page)

Alveolar recruitment manoeuvre in laterally recumbent anaesthetized sheep

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Background

- Sheep under general anaesthesia especially in lateral recumbency, develop hypoxaemia due to ventilation/perfusion inequality, atelectasis with an increase venous admixture (Qs/Qt) ^{1,2}
- Alveolar recruitment manoeuvre (ARM) is a ventilatory strategy that re-expands collapsed alveoli and keep them open subsequently using positive end-expiratory pressure (PEEP) ³
- A stepwise ARM applies progressive increases in PEEP and inspiratory peak pressure (Ppeak) to reopen area of atelectasis and improve alveolar ventilation.
- This technique improved arterial oxygenation and decrease Qs/Qt in dogs and horses ^{3,4} although no studies evaluate a stepwise ARM in sheep.
- F-shunt is a surrogate indicator of Qs/Qt that assume a fixed value of arterial-to-mixed venous oxygen content (C(a-v)O₂), equal to 3.5 mL dL⁻¹ and strongly correlates with venous admixture in sheep¹.

Aim

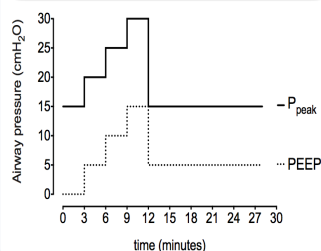
This study evaluates the efficacy of a stepwise ARM in improving oxygenation indices in left laterally recumbent, isoflurane anaesthetized sheep undergoing Magnetic Resonance Imaging.

Materials and methods

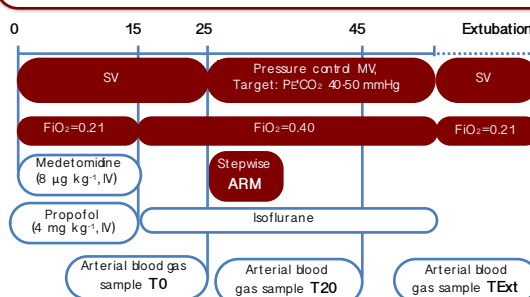
Animals

Six non-pregnant Brogna ewes
(39 ± 5 kg)

Alveolar recruitment manoeuvre



Procedure



ARM, alveolar recruitment manoeuvre; P_eCO₂, end expiratory partial pressure of carbon dioxide; FIO₂, fraction inspired of oxygen; MV, mechanical ventilation; SV, spontaneous ventilation. Time line expressed in minutes.

Formulas and measurements

$$CaO_2 = (Hb \times 1.31 \times SaO_2) + 0.0031 \times PaO_2$$

$$Cc'O_2 = (Hb \times 1.31 \times Sc'O_2) + 0.0031 \times Pc'O_2$$

$$Pc'O_2 = PAO_2 = (FIO_2 \times [Pbar - PH_2O]) - PaCO_2 \times 1.2$$

$$F\text{-shunt} = ((Cc'O_2 - CaO_2) / [Cc'O_2 - CaO_2] + 3.5 \text{ ml dl}^{-1}) \times 100$$

0.0031, solubility coefficient of oxygen in ovine plasma; 1.31, oxygen-carrying capacity of haemoglobin (ml, g⁻¹); CaO₂, arterial oxygen content (ml dL⁻¹); Cc'O₂, pulmonary end-capillary oxygen content (ml dL⁻¹); FIO₂, fraction inspired of oxygen; Hb, haemoglobin concentration (g dL⁻¹); PAO₂=(Pc'O₂), Alveolar or pulmonary end-capillary partial pressure of oxygen (mmHg); PaCO₂, Arterial partial pressure of carbon dioxide (mmHg); PaO₂, Arterial partial pressure of oxygen (mmHg); Pbar, barometric pressure (mmHg); PH₂O, vapour pressure of water (mmHg); SaO₂, Arterial haemoglobin oxygen saturation (%); Sc'O₂, pulmonary end-capillary haemoglobin oxygen saturation (%).

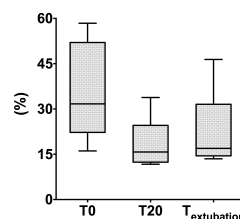
Because PAO₂ was > 100 mmHg in all sheep, Sc'O₂ was assumed to be 1²

Results

Variabile	T0	T20	TExt
FIO ₂	0.40	0.40	0.21
pH	7.357 ± 0.086a	7.385 ± 0.076a	7.402 ± 0.080b
PaO ₂			
mmHg	70 ± 28a	106 ± 25b	73 ± 13a
kPa	10 ± 4a	14 ± 3b	10 ± 2a
PaCO ₂			
mmHg	55 ± 7	54 ± 6	50 ± 7
kPa	7.4 ± 0.9	7.2 ± 0.8	6.7 ± 0.9
PAO ₂			
mmHg	239 ± 5a	241 ± 5a	108 ± 6b
kPa	31.9 ± 0.8a	32.1 ± 0.6a	14.4 ± 0.7b
SaO ₂			
%	93 (70-98)a	99 (91-99)b	96 (80-97)ab

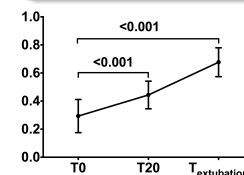
Data normally distributed are expressed as mean ± SD deviation otherwise as median (min-max). FIO₂, fraction inspired of oxygen; PAO₂, Alveolar partial pressure of oxygen; PaO₂, Arterial partial pressure of oxygen; PaCO₂, Arterial partial pressure of carbon dioxide; SaO₂, Haemoglobin oxygen saturation. Different letters in a row mean statistical significant difference (one-way ANOVA or Friedman non-parametric test p<0.05) between points.

F-shunts

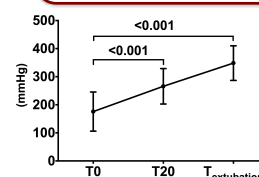


Median with interquartile range and min-max of F-shunt and mean ± SD of PaO₂/PAO₂ and PaO₂/FIO₂. One-way Anova or Friedman non-parametric test were used to analyse the data. Statistical significance was set at p<0.05.

PaO₂/PAO₂



PaO₂/FIO₂



Conclusion and clinical relevance

- General anaesthesia in laterally recumbent sheep under spontaneous ventilating may cause hypoxaemia as previously reported.²
- The stepwise ARM followed by mechanical ventilation with PEEP at 5 cmH₂O, improves the oxygenation indices and decrease the amount of venous admixture evaluated by the F-shunt.
- The positive effects of the ARM are still present in most of the animals at recovery.

References

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3. Canfrán S, Gómez de Segura IA, Cediel R et al. (2012) Vet J 194, 89-91.
4. Briganti A, Portela DA, Grasso S et al. (2015) Vet J 204, 351-356.

Ethical review

The study was approved by the Animal-welfare Body of the University of Padua (Authorization OPBA 7/2014) and the Italian Ministry of Health, according to European (Directive 2010/63/EU) and Italian regulations (Legislative Decree 26/2014)