Comparison of Three Methods for the Evaluation of Soundness of Pulmonary Function in Horses

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Soundness of the pulmonary system can be approached by various methods:

- Clinical examination (auscultation and percussion)
- Radiography of the thorax
- Pulmonary function tests
  - PaO_2
  - Data obtained by measuring intrathoracic pressure and respiratory volumes
  - Pulmonary hemodynamics
  - Nitrogen wash-in and wash-out
- Endoscopy and cytology of tracheal mucus

Question:

Is it necessary to include all these tests in the routine daily clinical work scheme or can one restrict the examination to the most reliable method?

The aim of the present investigation was to compare three function tests (PaO_2, data from intrathoracic pressure changes, respiratory volumes and pulmonary hemodynamics) in horses with one ore more of the following complaints:

- coughing
- nasal discharge
- pulmonary bleeding during or after exercise
- unsatisfactory performance
- delayed recovery after a race

Pulmonary function tests using intrathoracic pressure changes and respiratory volumes.

Table 1: Normal resting values in 10 trotters with satisfactory performances.

Resistance [kPa/l/sec]	0.072 ± 0.0215
Dynamic compliance [l/kPa]	17.6 ± 4.82
Delta PPl max [kPa]	0.88 ± 0.306
Respiratory rate [min^{-1}]	12.5 ± 3.92
V tidal [l]	6.4 ± 0.96
V min [l/min]	76.5 ± 22.94
Vt/Delta PPl [l/kPa]	6.76 ± 1.232
W visc [Joule]	2.65 ± 0.784
W visc/l [Joule/l]	0.21 ± 0.068
W visc/min [Joule/min]	32.5 ± 11.55
MIF [l/sec]	2.05 ± 0.688
MEF [l/sec]	2.49 ± 0.710
Exp/insp.time	1.00 ± 0.174
PaO_2 [mmHg]	100.1 ± 5.88
$PaCO_2$ [mmHg]	37.3 ± 1.95
Art. Blood PH	7.42 ± 0.406

Delta PPl max: maximal interpleural pressure difference; V tidal: tidal volume; V min: minute volume; Vt/Delta PPL: tidal volume – maximal interpleural pressure difference ratio; W visc: viscous work of breathing; MIF: mean inspiratory flow rate; MEF: mean expiratory flow rate; exp/insp.time: ratio between expiratory and inspiratory duration.

Pulmonary function tests in 10 horses with complaints of sporadic coughing, unsatisfactory performances and delayed recovery.

Table 2: Statistical differences from normal values (Student t test).

Resistance	0.09 ± 0.052	NS
Dynamic Compliance	14.66 ± 6.084	NS
Delta PPl max	1.20 ± 0.301	+
Resp. rate	18.18 ± 5.896	+
V tidal	5.57 ± 1.469	NS
V min	94.2 ± 39.84	NS
Vt/D PPl	4.64 ± 1.652	+ +
W visc	3.16 ± 1.236	NS
W visc/l	0.60 ± 0.235	NS
W visc/min	57.7 ± 38.63	NS
MIF	3.21 ± 1.243	NS
MEF	3.38 ± 1.560	NS
Exp/insp.time	0.98 ± 0.165	NS
PaO_2	87.30 ± 10.26	+ +

Compared with normal values, Delta PPl max (maximal pressure difference in the interpleural space) and respiratory rate, are both significantly higher in this group. Partial oxygen pressure in the arterial blood is very significantly lower.

Pulmonary hemodynamics measured with a balloon-tipped Swan-Ganz catheter.

Table 3: Normal values in 24 trotters with satisfactory performances.

Mean right atrial pressure (MRAP)	6.5 ± 2.89
Mean right ventricular pressure (MRVP)	16.9 ± 4.89
Mean pulmonary artery pressure (MPAP)	25.1 ± 4.32
Mean wedge pressure (MWP)	15.5 ± 3.39
Driving pressure (DP)	10.0 ± 2.10
PaO_2	100.2 ± 5.59

The pressure transducer was placed at the height of the scapula-humoral joint. The values are expressed in mm of mercury (mmHg).

The pulmonary wedge pressure is obtained by advancing the catheter in a branch of the pulmonary artery as far as possible. The balloon at the tip of the catheter is then inflated in order to eliminate the influence of the pulmonary artery pressure. The pressure measured at the tip of the catheter (distally to the balloon) is called the wedge pressure and is equal to the left atrial pressure.
The pulmonary driving pressure is the difference between the mean pulmonary artery pressure and the mean wedge pressure. The DP is the pressure needed to overcome the resistance in the pulmonary vascular bed. This resistance is largely influenced by the alveolar ventilation: alveolar hypoxia dramatically increases the vascular resistance (see Brisket Disease in cattle).

Hemodynamics in 81 horses suffering from COPD.

Table 4: Statistical comparison with normal values (Student t test).

	COPD	Normal	St.Diff.
MRAP	6.7 ± 3.36	6.5 ± 2.89	NS
MRVP	20.3 ± 5.14	16.9 ± 4.89	+ +
MPAP	33.9 ± 7.44	25.1 ± 4.32	+ +
MWP	16.1 ± 4.26	15.5 ± 3.39	NS
DP	17.8 ± 6.06	10.0 ± 2.10	+ +
PaO_2	81.7 ± 15.66	100.2 ± 5.59	+ +

Mean right ventricular pressure, mean pulmonary artery pressure, driving pressure and PaO_2 values in these horses affected with COPD are very significantly different from the values obtained in normal horses.
Measuring the pulmonary hemodynamics is a valuable method in diagnosing COPD in the horse.

Hemodynamics in 19 horses with complaints of unsatisfactory race performances, delayed recovery and repeated coughing after an effort as an indication of suspected left heart insufficiency.

Table 5: Statistical comparison with normal values (Student t test).

MRAP	9.2 ± 3.02	+ +
MRVP	23.4 ± 5.40	+ +
MPAP	35.5 ± 11.82	+ +
Wedge Pressure	24.3 ± 6.11	+ +
DP	11.1 ± 6.22	NS
PaO_2	97.6 ± 5.62	NS

Mean right atrial pressure, mean right ventricular pressure, mean pulmonary artery pressure and wedge pressure are very significantly different from normal values.
Measuring the pulmonary hemodynamics is a reliable method in the differential diagnosis between real pulmonary diseases and left heart problems, which, especially during an effort, can give rise to pulmonary oedema. In cases of left heart insufficiency, the DP remains normal but the wedge pressure is increased. The increase in MPAP in these cases is needed to overcome the wedge pressure.

Correlation between PaO_2 values, hemodynamics and the most relevant lung function levels in 45 horses with COPD.

Table 6: Correlation coefficients

PaO_2 values versus	Resistance	−0.32
	Compliance	+0.47
	Vt/PPI max	+0.68
	W visc/l	−0.53
	Delta PPI max	−0.55
	DP	−0.76
	MPAP	−0.73

Correlation between PaO_2 values, MPAP, Wedge pressure and DP in the first group of 81 Horses with COPD

Table 7: Correlation coefficients

PaO_2 versus	MPAP	−0.544
	DP	−0.605
	wedge pressure	+0.059

This work was supported by the Belgian Paris Mutuel Urbain (PMU)

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