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THE EFFECT OF COMMON BOVINE RESPIRATORY DISEASES ON TIDAL BREATHING FLOW-VOLUME LOOPS

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ABSTRACT

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In order to better understand the bovine breathing pattern, tidal breathing flow-volume loops (TBFVL) were analyzed in 24 healthy cattle of different body weights (range: 37–660 kg) (Group A) and in 28 cattle suffering from the common respiratory diseases: verminous bronchitis (Group B); shipping fever (Group C); acute respiratory distress syndrome (Group D); respiratory syncytial virus pneumonia (Group E); organophosphate poisoning (Group F); and necrotic laryngitis (Group G).

Respiratory airflow and tidal volume were measured with a breathing mask-Fleisch pneumotachograph assembly. TBFVL were traced from these values using a computerized method. All the loop indices proposed by Amis and Kurpershoek (1986a) were calculated from 5 representative breathing cycles for each of the 52 animals.

The TBFVL shapes and indices were relatively constant in most healthy cattle and were not correlated with the body size. When compared to normal values, animals with moderate respiratory syndromes (Groups B and C) had a more flattened shape to their TBFVL. On the other hand, in most cattle with severe respiratory pathologies (Groups D, F and G) expiration tended to be biphasic with the peak expiratory flow (PEF) occurring significantly later than in healthy animals. Both PEF and peak inspiratory flow were increased in all the pathological conditions. The TBFVL indices were more frequently and more severely changed during expiration than during inspiration.

INTRODUCTION

As in other species, measurement of the mechanics of breathing and gas exchange are essential for the study of the bovine respiratory system under both physiological and pathological conditions. However some parameters, such as the shape of the inspiratory and expiratory airflow curves, have not yet been investigated in cattle. Analysis of tidal breathing flow-volume loops (TBFVL) has been shown to be a simple and useful procedure for functional assessment of airway obstructive diseases in non-cooperative patients such as human infants (Abramson *et al.*, 1982) and dogs (Amis & Kurpershoek, 1986a; b; Amis *et al.*, 1986).

The purpose of this work was to study TBFVL in healthy cattle of different body weight and to evaluate the changes in the shape of TBFVL induced by the most common respiratory diseases in this species.

MATERIALS AND METHODS

Animals

Fifty two cattle were studied. The description of these animals was given in previous publications (Table I). When lung function was measured at different times, the loops

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TABLE I
Description of the experimental cattle used in this study

Groups	Clinical status	Number	Age (days)	Weight (kg)	References
A	Healthy	24	3–2760	37–660	Lekeux *et al.*, 1984b
B	Verminous bronchitis	5	205–215	164–198	Lekeux *et al.*, 1985a
C	Shipping fever	5	130–150	116–128	Lekeux *et al.*, 1987a
D	ARDS[1]	3	140–155	125–148	Lekeux *et al.*, 1985b
E	RSV[2] pneumonia	4	180–240	150–180	Lekeux *et al.*, 1985c
F	OP[3] poisoning	6	60–90	59–91	Lekeux *et al.*, 1986
G	Necrotic laryngitis	5	90–180	75–130	Lekeux *et al.*, 1987b

[1]: Acute respiratory distress syndrome
[2]: Respiratory syncytial virus
[3]: Organophosphate

TABLE II
Effect of common bovine respiratory diseases on some pulmonary function values

	Clinical status					
Values	B	C	D	E	F	G
f	169*	184*	332*	257*	141	161*
tI/tTOT	113*	109	102	113*	100	109*
VImax	116*	107	169*	144	136	144
VEmax	143*	119	209*	153*	164*	156*
VT	76*	64*	73	55*	96	87
Ve	133*	114	240*	151*	134	143*
maxΔPpl	161*	125*	346*	175*	567*	857*
PplFRC	122	124	129	77*	25*	125
Cdyn	52*	76*	21*	26*	21*	24*
RL	130*	181*	100	150*	481*	752*
Wvis	222*	197*	679*	302*	840*	821*
PaO_2	71*	74*	38*	58*	56*	79*
$PaCO_2$	121	90	134	107	105	107

See Table I for references and description of clinical state.
Data are expressed as the percentage of reference values for healthy cattle.
*: significantly different from reference values for $P<0.05$ (one-tailed t-test).
f: respiratory frequency; tI/tTOT: inspiratory time/total time of the breathing cycle ratio; VImax and VEmax: peak inspiratory and expiratory airflow; VT: tidal volume; Ve: minute volume; maxΔPpl: peak to peak change in pleural pressure; PplFRC: Ppl at the level of functional residual capacity; Cdyn: dynamic lung compliance; RL: total pulmonary resistance; Wvis: minute viscous work of breathing; PaO_2 and $PaCO_2$: arterial oxygen and carbon dioxide tensions.

were generated for the period when the disease was most severe, eg, 5 weeks after infection for verminous bronchitis and 1 day after the clinical onset of the disease for respiratory syncytial virus pneumonia. The pulmonary function values for these 52 animals were previously reported (Table I) and are compared in Table II.

Procedures

A breathing mask-Fleisch pneumotachograph (Gould) assembly was used to measure respiratory airflow as previously described (Lekeux *et al.*, 1984a). Tidal volume (VT) was derived electronically by integrating airflow with respect to time. Calibration was performed with a flow calibration set (Gould). Data were recorded in resting, non-anesthetized, and unsedated cattle under standardized conditions for air pressure, room temperature and body position. Airflow and VT were recorded simultaneously on a rapid writing polygraph (Gould ES 1000). TBFVL were traced from these curves using a computerized method. All the loop shape indices proposed by Amis and Kupershoek (1986a) were calculated from five representative, regular and artifact-free breathing cycles and averaged for each animal. In order to allow comparisons between cattle of different body size, only TBFVL ratios were analyzed (Table III). These indices were based on the peak inspiratory and expiratory flow (PIF and PEF), the midtidal inspiratory and expiratory flow (IF50 and EF50) and inspiratory and expiratory flow at end expiratory volume plus 25% VT (IF25 and EF25).

Statistical analysis

Data are given as mean ± standard error. The effect of body size on the TBFVL ratios was evaluated using linear regression analysis. Data from diseased cattle were compared with data from healthy ones by a one-way analysis of variance (ANOVA).

RESULTS

The shape of the TBFVL was relatively constant in most healthy cattle (Figure 1A). PEF occurred at the beginning of expiration (end expiratory volume plus 77.2±1.8% VT) and was followed by a progressive decrease in flow velocity. The inspiratory part of their loop was more rounded than the expiratory part. The PIF occurred at the end expiratory volume plus 48±6% VT.

Linear regressions of TBFVL ratios on body weight in healthy cattle are given in Table III. The effect of somatic growth on the loop indices was shown to be negligible.

Animals with moderate respiratory syndromes (Groups B and C) had a more flattened shape for their TBFVL (Figures 1B and 1C). On the other hand, in most cattle with severe respiratory syndromes (Groups D, F and G) expiration tended to be biphasic with the PEF occurring significantly later than in healthy cattle (end expiratory volume plus 44±3% VT) (Figures 1D, F and G). However 2 animals in Group F and 1 in Group G had a loop shape similar to that observed in healthy cattle, although these animals were as severely affected as others within the same group.

Changes in the TBFVL indices during common respiratory diseases are given in Figure 2. Three, 5, 5, 4, 2 and 3 loop indices were significantly modified in Groups B, C, D, E, F and G respectively, when compared to control values.

The loop shapes and indices were more frequently and more severely changed during expiration than during inspiration in diseased animals. Thus, the inspiratory and expiratory TBFVL ratios were significantly changed 2 and 10 times respectively (Figure 2).

DISCUSSION

The technique used in this study for recording the TBFVL is different to the one reported by Amis and Kurpershoek (1986a) in dogs where an X-Y recorder was used. Our method is more laborious but presents some advantages: 1) the phase lag between

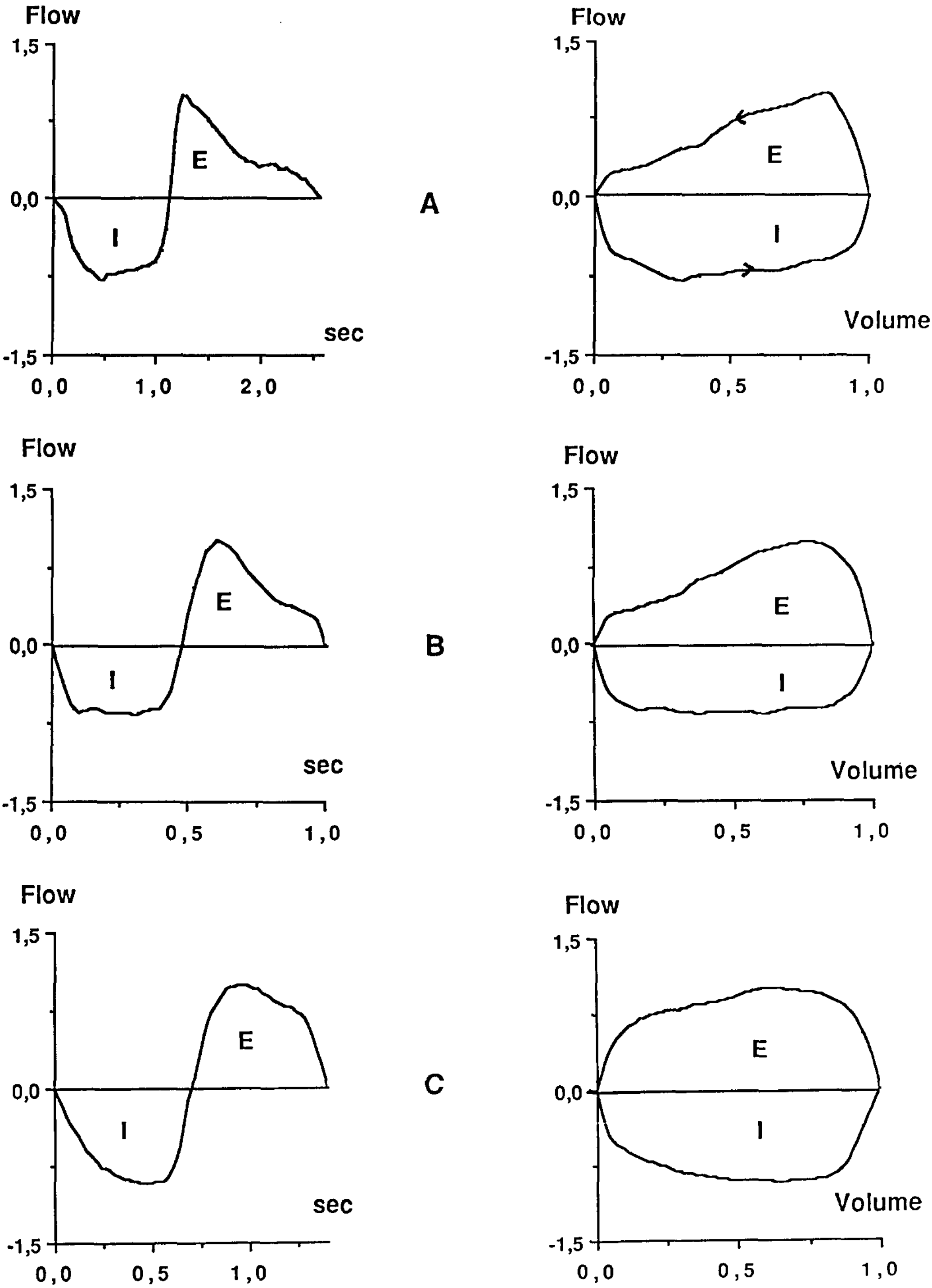

Figure 1A, 1B, 1C

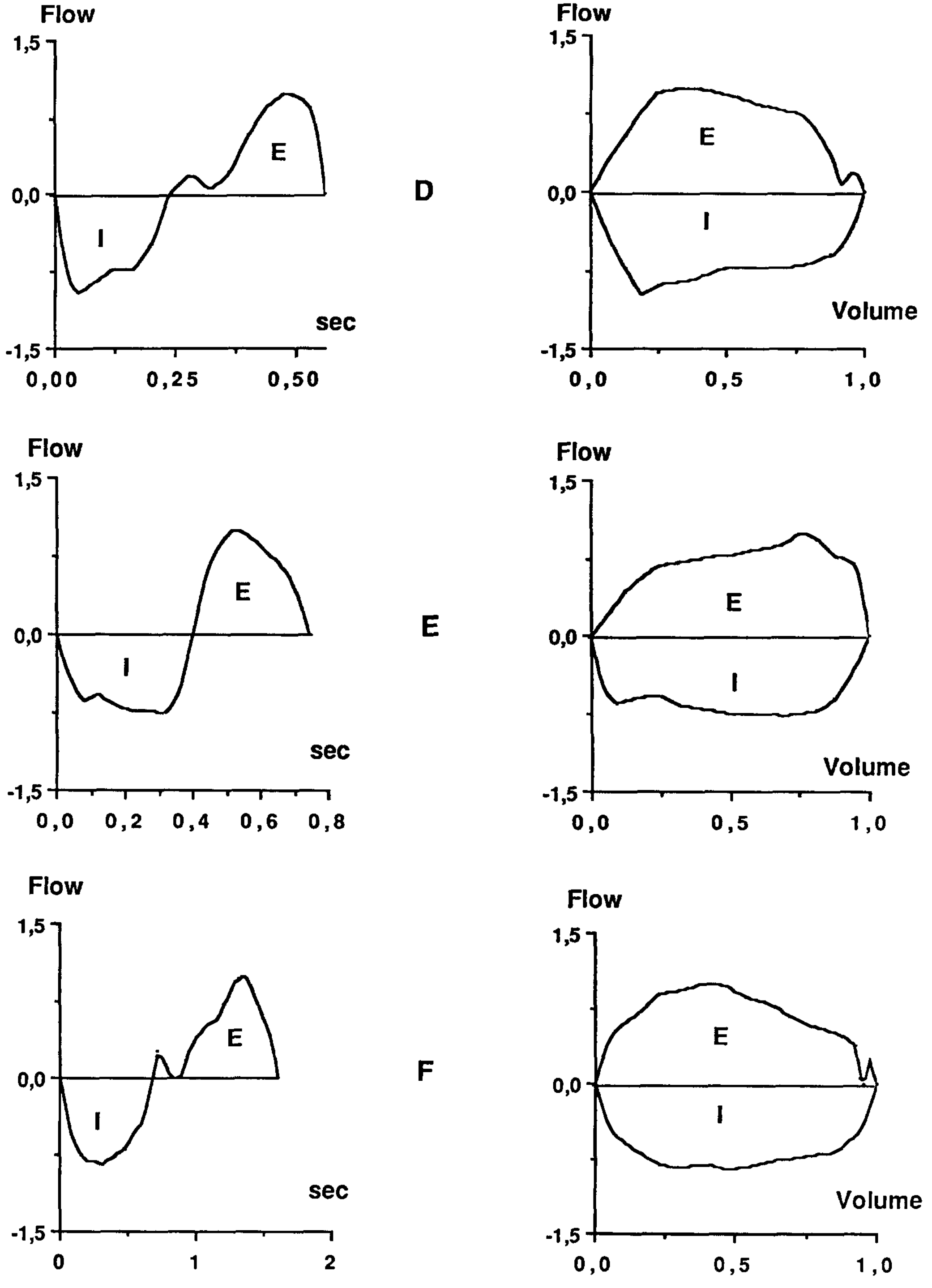

Figure 1D, 1E, 1F

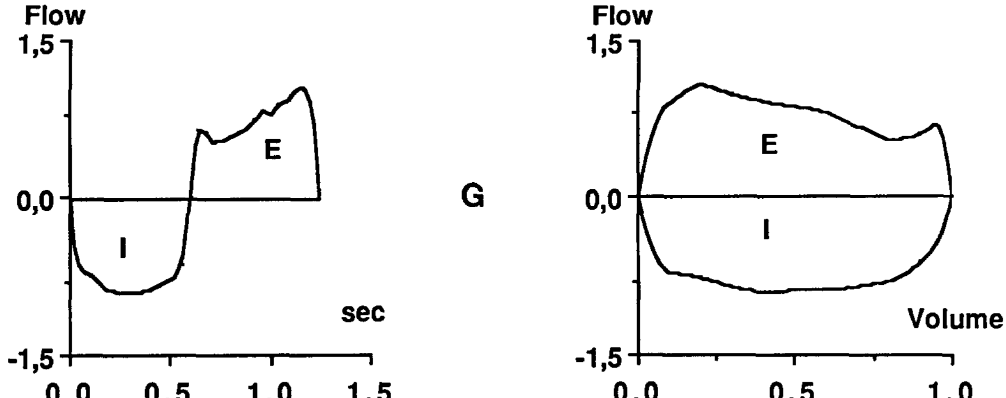

Figure 1G

Figure 1. Typical airflow curves and tidal breathing flow-volume loops in healthy (A) and diseased (B to G) cattle. Flow and volume data are expressed as the ratio of peak values. See Table I for key.

the 2 signals during high respiratory rates is avoided; 2) the selection of regular and representative breathing cycles is easier; 3) the simultaneous study of apneic periods and the measurement of some temporal values such as tI/tTOT (Table II) are possible.

TBFVL analysis has not previously been reported in cattle. The loop shapes and indices from our healthy cattle are in agreement with data from healthy dogs (Amis & Kurpershoek, 1986a). As in dogs, there was no relation between the body weight and the loop ratios in healthy cattle. This allows comparisons between animals of different body sizes.

As in human adults (Proctor *et al.*, 1950), infants (Abramson *et al.*, 1982) and dogs (Amis & Kurpershoek, 1986b; Amis *et al.*, 1986), TBFVL analysis gives interesting information about the strategy of breathing in diseased cattle. Necrotic laryngitis cattle have TBFVL that are similar to dogs with upper airway obstruction (Amis & Kurpershoek, 1986b). Furthermore, most cattle with lower airway obstructive diseases had flattening of the expiratory loops, although the absolute value of their PEF was higher

TABLE III
Linear regressions of loop indices on body weight (BW) in 24 healthy cattle

Loop indices	a	b	R^2	DS
PEF/PIF	1.160	-22.10^{-5}	0.076	NS
EF50/IF50	1.079	-29.10^{-5}	0.147	NS
EF25/IF25	0.800	-33.10^{-5}	0.176	*
PEF/EF50	1.169	$+18.10^{-5}$	0.081	NS
PEF/EF25	1.722	$+32.10^{-5}$	0.019	NS
EF50/EF25	1.461	$+5.10^{-5}$	0.002	NS
PIF/IF50	1.082	$+4.10^{-5}$	0.007	NS
PIF/IF25	1.142	-10.10^{-5}	0.081	NS
IF50/IF25	1.056	-12.10^{-5}	0.059	NS

$X = a + b \times BW$ (kg)
R^2: Determination coefficient
DS: Degree of significance of the variance ratio
NS: Non-significant; $^*P \leq 0.05$

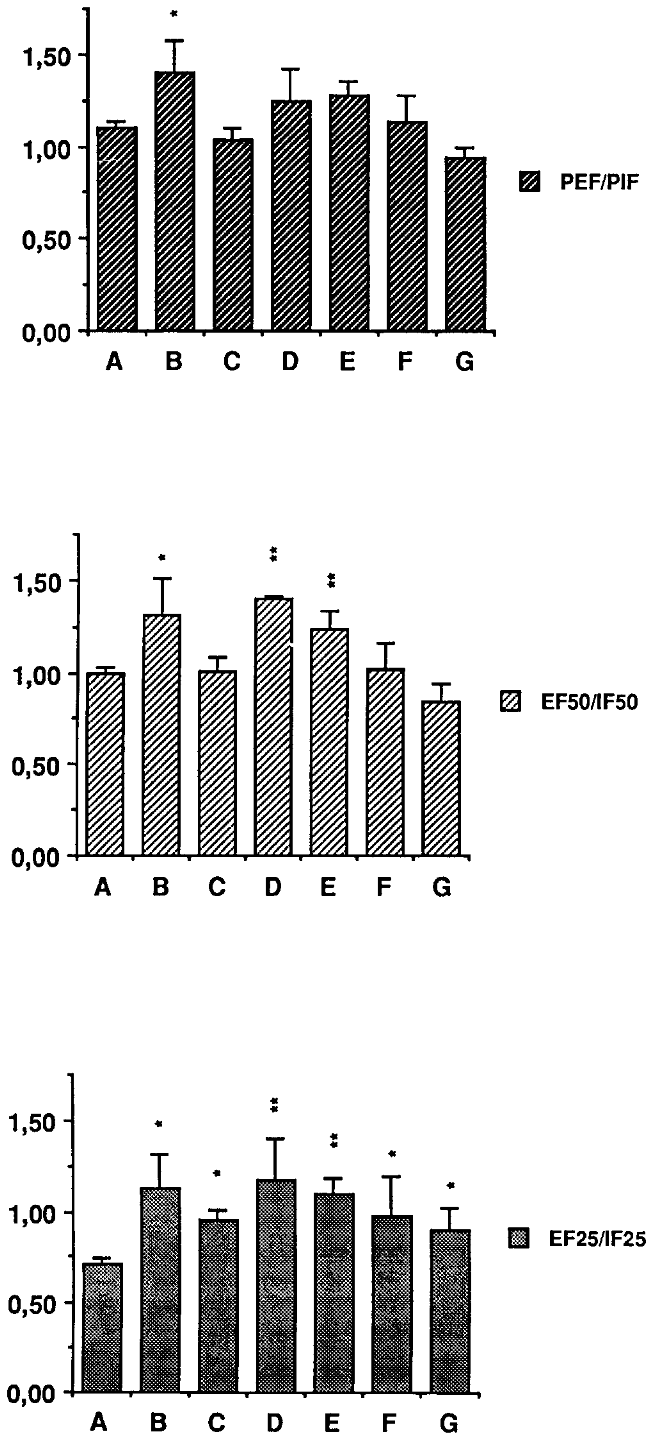
1,50
1,00
0,50
0,00
A B C D E F G
PEF/PIF
1,50
1,00
0,50
0,00
A B C D E F G
EF50/IF50
1,50
1,00
0,50
0,00
A B C D E F G
EF25/IF25

Figure 2A

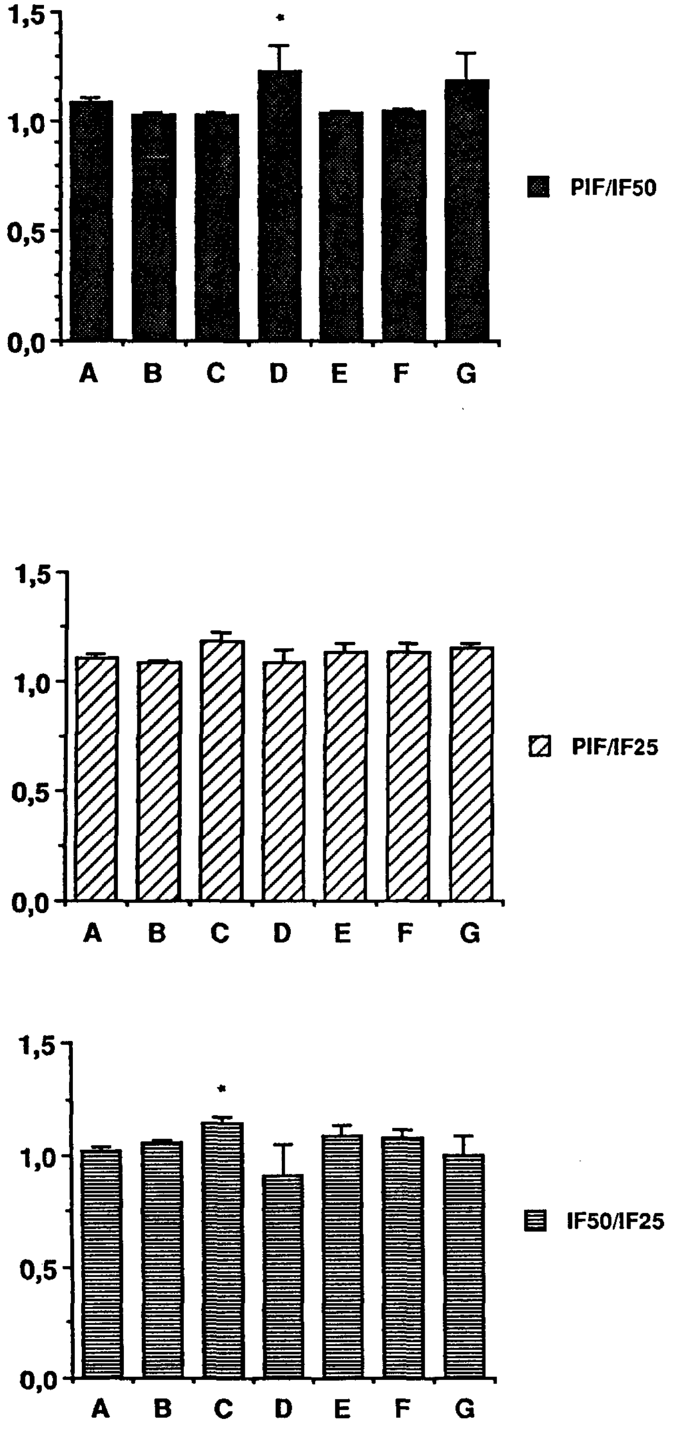
1,5
1,0
0,5
0,0
*
A B C D E F G
PIF/IF50
1,5
1,0
0,5
0,0
A B C D E F G
PIF/IF25
1,5
1,0
0,5
0,0
*
A B C D E F G
IF50/IF25

Figure 2B

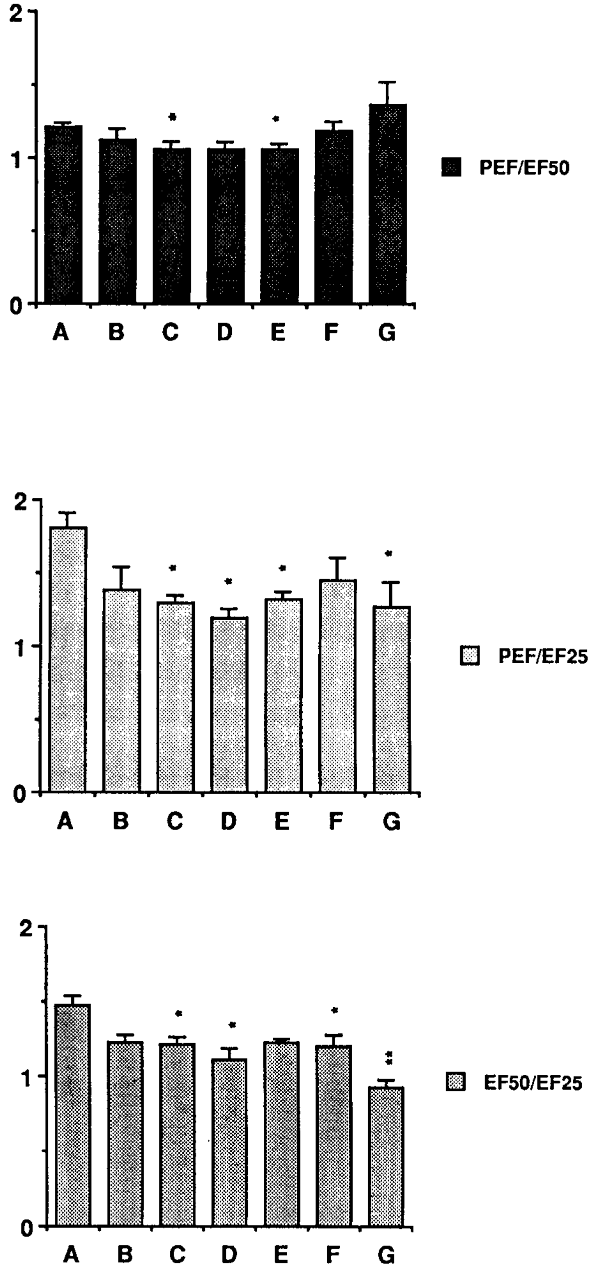

Figure 2C

Figure 2. Effect of common bovine respiratory diseases on tidal breathing flow-volume loops indices.
See Table I for key. Data are given as mean ± SE.
* Significantly different from group A (P<0.05)
** P<0.01

than in healthy animals. The change in their breathing pattern (decreased VT with increased respiratory frequency) may explain this phenomenon. This may be partly correlated with the morphology of the bovine respiratory system, namely the absence of collateral ventilation (Robinson, 1982) and, thus, the frequent presence of trapped gas in diseased lungs.

The most spectacular change in the strategy of breathing observed in some of our diseased animals was biphasic expiration. This abnormality seems to be better correlated with the severity of the respiratory distress than with the site of the pathological process. Indeed, biphasic expiration was recorded in cattle with extrathoracic airway obstruction (Group G), intrathoracic airway obstruction (Group F) and alveolar disease (Group D). The fact that it is mainly observed in diseased animals with the highest minute viscous work of breathing (Table II) suggests that the force of lung elasticity was being supplemented by the respiratory muscles in order to produce a sufficiently fast expiration and that this TBFVL change may be associated with respiratory muscle fatigue (Milic-Emili, 1983).

On the other hand, the clinical and diagnostic usefulness of TBFVL analysis is less evident in cattle than in dogs. Measurement of intrapleural pressure in unsedated animals is much easier in this species than in dogs (Kiorpes *et al.*, 1978) and can be used for more complete pulmonary function testing (Lekeux *et al.*, 1984b). Furthermore, forced oscillations, another non-invasive technique, has been shown to be a simple, accurate and highly interesting method of investigating lung function in unsedated cattle (Gustin *et al.*, 1987).

REFERENCES

Abramson, A. L., Goldstein, M. N., Stenzler, A. & Steele, A. 1982. The use of the tidal breathing flow volume loop in laryngotracheal disease of neonates and infants. *Laryngoscope*, **92**, 922–927

Amis, T. C. & Kurpershoek, C. 1986a. Pattern of breathing in brachycephalic dogs. *American Journal of Veterinary Research*, **47**, 2200–2204

Amis, T. C. & Kurpershoek, C. 1986b. Tidal breathing flow-volume loop analysis for clinical assessment of airway obstruction in conscious dogs. *American Journal of Veterinary Research*, **47**, 1002–1006

Amis, T. C., Smith, M. M., Gaber, C. E. & Kurpershoek, C. 1986. Upper airway obstruction in canine laryngeal paralysis. *American Journal of Veterinary Research*, **47**, 1007–1010

Gustin, P., Dhem, A. R., Lomba, F., Lekeux, P. & Landser, F. J. 1987. *Effect of histamine inhalation on the bovine pulmonary function: a comparison of two techniques of investigation*, (6th Comparative Respiratory Society Meeting, Chicago), 6 pp

Kiorpes, A. L., Bisgard, G. E. & Manohar, M. 1978. Pulmonary function values in healthy Holstein-Friesian calves. *American Journal of Veterinary Research*, **39**, 773–778

Lekeux, P., Hajer, R., & Breukink, H. J. 1984a. Pulmonary function testing in calves: technical data. *American Journal of Veterinary Research*, **45**, 342–345

Lekeux, P., Hajer, R. & Breukink, H. J. 1984b. Effect of somatic growth on pulmonary function values in healthy Friesian cattle. *American Journal of Veterinary Research*, **45**, 2003–2007

Lekeux, P., Hajer, R. & Breukink, H. J. 1985a. Longitudinal study of the effects of lungworm infection on bovine pulmonary function. *American Journal of Veterinary Research*, **46**, 1392–1395

Lekeux, P., Hajer, R., Van Den Ingh, T. S. G. A. M. & Breukink, H. J. 1985b. Pathophysiologic study of 3-methylindole-induced pulmonary toxicosis in immature cattle. *American Journal of Veterinary Research*, **46**, 1629–1631

Lekeux, P., Verhoeff, J., Hajer, R. & Breukink, H. J. 1985c. Respiratory syncytial virus pneumonia in Friesian calves: physiological findings. *Research in Veterinary Sciences*, **39**, 324–327

Lekeux, P., Kyavu, A., Clercx, C. & Ansay, M. 1986. Pulmonary function changes induced by experimental dichlorvos toxicosis in calves. *Research in Veterinary Sciences*, **40**, 318–321

Lekeux, P., Art, T., Gustin, P. & Clercx, C. 1987a. Effet des pathologies respiratoires sur la fonction pulmonaire des bovins à l'engraissement. *Annals de Médecine Vétérinaire*, **131**, 295–302

Milic-Emili, J. 1983. Respiratory muscle fatigue and its implications in RSD. In E. V. Cosini & E. M. Scarpelli (eds), *Pulmonary Surfactant System,* (Elsevier, Amsterdam), 135–141

Proctor, D. F., Hardy, J. B. & McLean, R. 1950. Studies of respiratory airflow: II observations on patients with pulmonary diseases. *Bulletin of the Johns Hopkins Hospital,* **87,** 255–289

Robinson, N. E. 1982. Some functional consequences of species differences in lung anatomy. *Advances in Veterinary Sciences & Comparative Medicine,* **26,** 1–33

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