

STUDIES ON THE PHYSIOPATHOLOGY OF CHRONIC OBSTRUCTIVE PULMONARY DISEASE IN THE HORSE. III. THE INTRATHORACIC PRESSURE

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ABSTRACT

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The intrathoracic pressure was determined by direct intrapleural cannulation in 17 clinically normal horses and 14 horses with chronic obstructive pulmonary disease (COPD). There were significant differences between the normal and COPD horses with regard to max. Ppl and max. Δ Ppl. The mean values for minimum Ppl of the 2 groups of subjects were not significantly different. The results were discussed in relation to those of other workers.

Résumé

ÉTUDES SUR LA PHYSIOPATHOLOGIE DE LA MALADIE PULMONAIRE OBSTRUCTIVE CHRONIQUE DU CHEVAL. III. LA PRESSION INTRATHORACIQUE

La pression intra-thoracique a été déterminée par cannulation intra-pleurale directe chez 17 chevaux cliniquement normaux et chez 14 chevaux atteints de la maladie pulmonaire obstructive chronique (COPD). On a trouvé des différences significatives entre les chevaux normaux et les chevaux COPD en ce qui concerne le max. Ppl et le max. Δ Ppl.

Les valeurs moyennes pour un minimum Ppl des deux groupes de sujets ne furent pas significativement différentes. Les résultats ont été discutés en rapport avec ceux obtenus par d'autres chercheurs.

INTRODUCTION

Throughout the respiratory cycle in normal man, the pressure in the thoracic cavity (Ppl) is negative with respect to ambient barometric pressure (Mead & Gaensler, 1959). Negative pressures varied from c. -12 cm H₂O at end-inspiration to $-5,1$ H₂O at end-expiration, and thus the mean intrathoracic pressure difference (Δ Ppl) was c. $6,9$ cm H₂O. When simultaneous measurements were made by the oesophageal balloon technique, absolute values were less negative than those obtained directly.

In horses, the reported values for minimum and maximum Ppl vary markedly, ranging from $27,2$ cm H₂O (Spörri & Zerobin, 1964) to $-1,0$ cm H₂O (Gillespie, 1965) for maximum Ppl, and from $-81,6$ cm H₂O (Spörri & Zerobin, 1964) to $-19,0$ cm H₂O (Spörri & Denac, 1967) for minimum Ppl. In a series of 53 normal horses at sea-level, Sasse (1971) determined the following mean values:

Minimum Ppl: $-13,6 \pm 3,4$ cm H₂O
Maximum Ppl: $-3,4 \pm 2,0$ cm H₂O
Max. Δ Ppl: $+10,3 \pm 2,9$ cm H₂O

The technique of choice in man is the intra-oesophageal balloon because there is an understandable reluctance on the part of medical physiologists to invade the thoracic cavity. In horses, a number of determinations of Ppl have been made using the intrapleural cannulation technique (Spörri & Zerobin, 1964; Sasse, 1971; McPherson & Lawson, 1974). According to Spörri & Zerobin (1964) the intra-oesophageal balloon technique gave unsatisfactory results.

McPherson & Lawson (1974) compared both techniques and stated that the balloon method indicated abnormal pressure changes when they were present and their figures demonstrated a good correlation between the results obtained by the 2 techniques. However, they agreed with Sasse (1971) that the intrathoracic cannulation method gave the true reading in all cases. Gillespie, Tyler & Eberly (1966) compared intra-oesophageal pressures with intrathoracic pressures in 3 horses and found that the pressure changes

measured by the 2 methods did not vary more than $\pm 0,5$ cm H₂O when the total intrathoracic pressure change was less than 10 cm H₂O.

The intra-oesophageal balloon method measures not only intrathoracic pressure but also the pressures exerted by the oesophageal wall and peri-oesophageal tissue. The properties of the balloon itself and its position in the oesophagus also affect readings (Banchemo, Rutishauser, Tsakiris & Wood, 1967). Intra-oesophageal pressures in dogs were found to be less negative than intrathoracic pressures measured at the same level by intrapleural cannulation (Banchemo, Schwarz, Tsakiris & Wood, 1967). The data published by McPherson & Lawson (1974) suggested that the same obtains in horses.

In 38 horses with COPD (diagnosed at autopsy), Sasse (1971) found that intrathoracic pressures of horses in which he had diagnosed chronic obstructive pulmonary disease (COPD) differed highly significantly from those of clinically normal horses. The mean values which he recorded were:

Minimum Ppl: $-21,3 \pm 5,3$ cm H₂O
Maximum Ppl: $+4,0 \pm 6,2$ cm H₂O
Max. Δ Ppl: $25,3 \pm 8,8$ cm H₂O

The present study was designed to investigate the intrathoracic pressures of normal and COPD horses by direct cannulation, the technique used by Sasse (1971) for similar studies in horses kept at sea-level.

MATERIALS AND METHODS

Subjects. The group of clinically normal horses and ponies consisted of 7 privately owned and 10 experimental subjects in Departmental stables of this Faculty. No signs of pulmonary or cardiac disease were noted at any time during the investigation, and all were in some form of productive work.

The 14 COPD horses and ponies were clinical cases referred by veterinarians to the Department of Medicine of this Faculty. Although COPD was diagnosed or suspected by the referring veterinarian, the animals were assigned to the COPD category only after a complete clinical examination as described by Littlejohn (1980).

Equipment. Intrathoracic pressure changes were measured by direct intrapleural cannulation used in conjunction with a Satham pressure transducer, an electromanometer equipped with booster amplifier, and with the writing device incorporated in the Mingograf-81 physiological recorder.

The technique used was as follows:

A site at the 10th intercostal space on a line drawn from the point of the shoulder to the tuber ilii on the right side was shaved and disinfected with tincture of iodine. After subcutaneous and deep infiltration of the site with 2% lignocaine HCl, a tiny incision was made with a scalpel through the skin only. The incision was just large enough to allow for the easy passage of a trochar and cannula 7,5 cm in length and 1,5 mm in internal diameter.

The trochar was then inserted carefully through the skin incision and intercostal muscles, and finally through the pleura itself, care being taken to direct the cannula close to the anterior border of the 11th rib to avoid trauma to the intercostal vessels.

Penetration of the parietal pleura was recognized by the hiss of atmospheric air passing into the intrapleural space when the trochar was removed.

The Satham pressure transducer, which meanwhile had been calibrated by an assistant, was then attached directly to the cannula. Sterile physiological saline solution was pumped through the head of transducer EMT 35 and into the cannula by means of a Harvard Liquid Pump.* This was necessary because (a) the transducer head was designed to be used with liquid, and (b) the response of the transducer was much more stable when both the transducer head and the cannula were filled with liquid than if only the transducer head was filled.

A flow rate of 0,02 ml/min was used, as recommended by Sasse (1971), and no deleterious effects were observed in subjects as a result of cannulation or the slow injection of a fraction of a ml of sterile saline solution into the thoracic cavity.

The electromanometer was regularly calibrated against a mercury manometer for positive pressures. Negative pressures were checked by attaching a water-filled polyethylene cannula to the transducer head and lowering the tip of the cannula 136 cm below the transducer head, thus equalling -100 mm Hg. Internal calibration of the electromanometer was carried out before and after each recording of intrathoracic pressure curves.

As a precaution and routinely, 2 500 000 iu of procaine penicillin G plus 2,5 g of dihydro-streptomycin was injected intrathoracically before the cannula was finally withdrawn.

RESULTS

The results of the intrathoracic pressure measurements are tabulated in Table 1. Three measurements were obtained from the curves, examples of which are shown in Fig. 1 & 2. The measurements were identical with those selected by Sasse (1971), viz.:

- (a) The Minimum intrapleural pressure during inspiration (Min. Ppl)
- (b) The maximum intrapleural pressure during expiration (Max. Ppl), and
- (c) The maximum intrapleural pressure difference, i.e. the difference between (a) and (b) in each subject (Max. ΔPpl).

Significant differences between the mean values obtained for the above parameters in normal and COPD horses were observed for (b) and (c), but not for (a).

TABLE 1 Intrathoracic pressures in normal and COPD subjects

		Normal n=17	COPD n=14	Difference of means	Signifi- cance
Min. Ppl cm H ₂ O (Inspiration).....	Mean SD	-14,4 ± 5,6	-15,6 ± 8,8	1,1	t=0,43 Ns
Max. Ppl cm H ₂ O (Expiration).....	Mean SD	- 6,5 ± 4,4	+ 2,6 ±11,5	9,1	t=2,65 P<0,01
Max. ΔPpl cm H ₂ O.....	Mean SD	+ 7,9 ± 3,3	+17,7 ±13,8	9,8	t=2,82 P<0,01

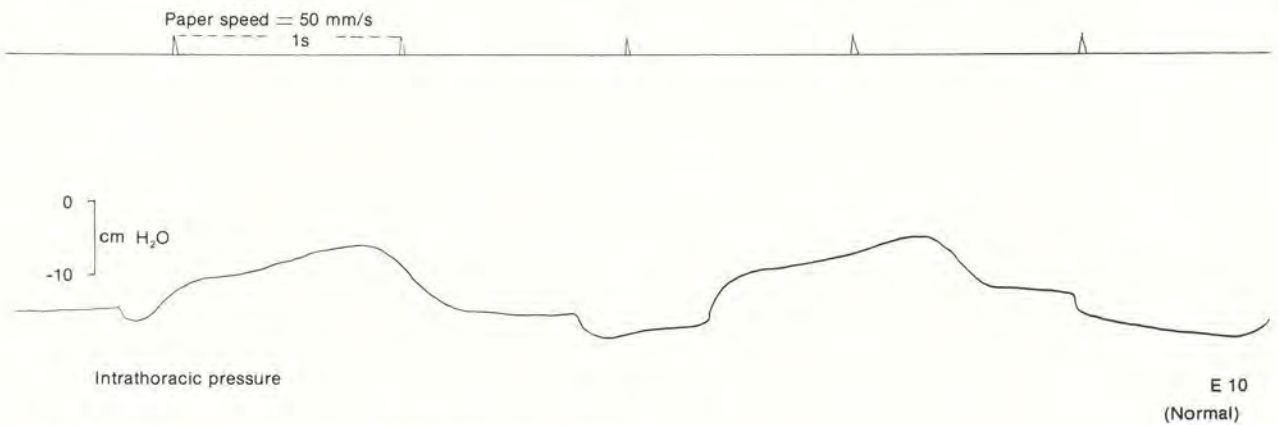


FIG. 1 Intrathoracic pressure curve of normal subject No. E10

* No. 1993 Series 940

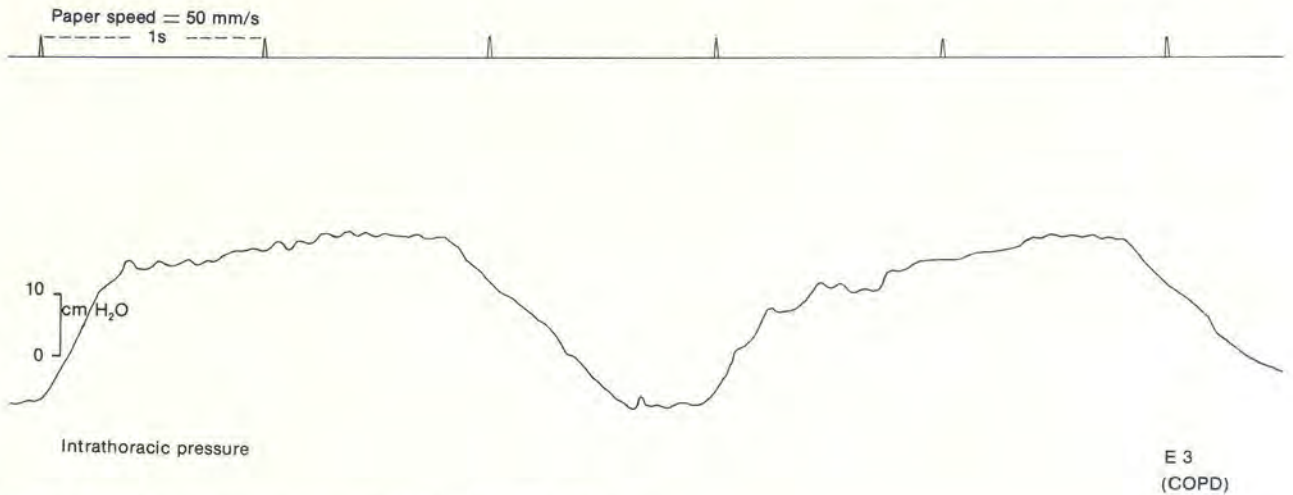


FIG. 2 Intrathoracic pressure curve of COPD subject No. E3

DISCUSSION

For normal subjects the mean minimal intrapleural pressure was -14.4 cm H₂O and the mean maximum intrapleural pressure was -6.5 cm H₂O. Both were slightly more negative than the corresponding means of -13.6 cm H₂O and -3.6 cm H₂O recorded in 24 normal horses by Sasse (1971).

There appears to be no information regarding the effect of altitude on intrapleural pressures in man or animals. However, it is possible that such an effect exists and that the increased negativity of the intrapleural pressure recorded was a compensatory mechanism of some kind induced by altitude and the consequent lower barometric pressure. The mean maximum intrathoracic pressure difference was somewhat smaller than that determined by Sasse (1971) in 24 normal subjects. The mean Max. Δ Ppl of the 17 normal subjects of the present series was 7.9 ± 3.3 cm H₂O, whereas the corresponding values determined by Sasse (1971) were 10.3 ± 2.9 cm H₂O.

Gillespie *et al.* (1966) measured intrapleural pressures in normal and emphysematous horses by means of the oesophageal balloon technique. They obtained mean values of 3.59 cm H₂O and 9.65 cm H₂O for Max. Δ Ppl in 19 normal and 13 COPD horses respectively.

Using the intrapleural cannulation technique, Spörri & Denac (1967) obtained mean values of -19 cm H₂O and -2.7 cm H₂O for minimum and maximum intrapleural pressures respectively. However, they did not record the exact position of the cannula. Since the site of cannulation has an effect upon the results obtained for intrapleural pressures in dogs (Banchero *et al.*, 1967), it is likely that the site chosen by Spörri & Denac (1967) was somewhat nearer to the dorsal border of the thoracic cavity than in the cases investigated by Sasse (1971) and in the present studies. The mean values for minimum and maximum intrapleural pressures in COPD horses in this study were not as great as those of Sasse (1971), who reported means of -21.3 cm H₂O and 4.9 ± 6.2 cm H₂O respectively, in 14 subjects in which COPD was diagnosed at post-mortem examination. In a further 29 cases of clinical COPD, his mean figures were -21 ± 4.1 cm H₂O and 5.7 ± 5.6 cm H₂O for minimum and maximum Ppl respectively. Max. Δ Ppl values in excess of 8.16 cm H₂O were regarded by McPherson,

Lawson, Murphy, Nicholson, Fraser, Breeze & Pirie (1978) as an important criterion for identifying COPD.

The present results, like those reported by Gillespie *et al.* (1966) and Sasse (1971), demonstrated a significant increase in maximum Ppl in the COPD subjects. The increase was somewhat less than that reported by Sasse (1971) and somewhat greater than that reported by Gillespie *et al.* (1966).

The lack of significant increase in the minimum intrapleural pressure of COPD subjects is difficult to explain.

A generalization is possible from the data that the increase in the maximum intrapleural pressure difference in COPD subjects was due mainly to an increase in the maximum intrapleural pressure during expiration. In this series the appearance of a positive maximum intrathoracic pressure indicated a greater than usual Max. Δ Ppl.

Sasse (1971) concluded that the maximum intrathoracic pressure difference was a very important diagnostic aid. The results of these investigations are in agreement with that observation and it is perhaps significant that, of the present series of 14 COPD subjects in which intrathoracic pressures were recorded, the only 3 which returned to normal work after treatment were those in which a negative maximum intrathoracic pressure during expiration was recorded. According to Neergard & Wirz (1927), an increase in Ppl is associated with increased bronchial (or bronchiolar) resistance. It may be that the development of positive intrapleural pressure in horses is indicative of irreversible changes in lung structure or function, or both.

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