EFFECT OF RUMEN INSUFFLATION ON RUMINAL CONTRACTION RATE IN SHEEP

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SUMMARY

Rumen motility trials were conducted on sheep fitted with rumen cannulas. The tracheal transection technique was used to ascertain eructation in order to identify secondary rumen contractions.

Increases in intrarumen pressure resulted in a linear increase in primary contraction frequency at pressures below approximately 10 cm H2O and a suppressing effect at pressures exceeding this level. Secondary contraction frequency increased linearly with increasing intrarumen pressure. The frequency of total rumen contractions increased as intrarumen pressure increased.

Nitrogen, compressed air, a carbon dioxide-methane gas mixture (60:40) and human expired air were used during the insufflation trials. The presence of carbon dioxide in the gases used during insufflation resulted in a significant increase in primary contractions at intrarumen pressures exceeding 10 cm H2O. Gases containing carbon dioxide resulted in a lower secondary contraction frequency than those gases free of carbon dioxide and consequently a lower total rumen contraction frequency.

For there to be a difference in the frequency of primary and secondary contractions caused by different insufflation gases and pressures suggests separate centers for these types of contractions. There is probably a maximum rumen contraction rate that is dictated by refractory periods in the motility centers and/or musculature of the rumen. Within the contraction rate limits, reciprocal innervation of centers controlling primary and secondary contractions probably occurs.

In view of the findings, it becomes necessary to consider the influence on gastric centers of the gases produced in the rumen, in addition to stimuli arising from rumen presso- and mechanoreceptors.

(Key Words: Rumen Motility, Contractions, Frequency, Insufflation, Pressure, Sheep.)

INTRODUCTION

Early rumen insufflation studies were mainly qualitative in nature and concerned with the etiology and/or cause of death due to bloat (Dougherty, 1942; Nichols, 1951; Quin, 1943; Weiss, 1953; Wester, 1926).

Recent rumen insufflation experiments by Stevens and Sellers (1959), Reid and Titchen (1965), Ruckebusch and Tomov (1973) and Kölling (1974) have been more concerned with the effects of insufflating the rumen with gas on the frequency and amplitude of rumen contractions. It has been found that moderate insufflation of gas into the rumen led to an increase in the number of rumen contractions, especially the number of secondary contractions (Kölling, 1974; Reid and Titchen, 1965; Ruckebusch and Tomov, 1973; Stevens and Sellers, 1959; Weiss, 1953).

Very little information can be found comparing different types of gas used during the insufflation trials. Dougherty (1942) observed that oxygen resulted in a more marked increase in rumen activity than when nitrogen was used. On the other hand, Reid and Titchen (1965) noted no differences in rumen motility when either 5% carbon dioxide in oxygen, nitrogen or carbon dioxide-methane (60:40) was insufflated.

The objectives of this study were twofold: First, to further investigate the quantitative effects of resting intrarumen pressure on rumen contraction rate, and second, to ascertain whether the type of gas used during insufflation affects contraction rate.

EXPERIMENTAL PROCEDURES

The experimental animals were four Targee-Finn ewes with an average body weight of 47
kilograms. They were housed in separate cages in a room maintained at 20°C. The diet consisted of approximately 1 kg of good quality hand-shredded alfalfa hay and .25 kg fat lamb pellets per day. Water and salt blocks were available ad libitum.

Each animal had a permanent rumen cannula (Colvin et al., 1965) that had been modified by the substitution of the syringe barrel with flexible Silastic tubing (O.D. 1.6 cm, I.D. .9 cm). Cemented around the Silastic tubing approximately 1 cm above the flange was a Dacron band to which the outer rumen wall, peritoneum, abdominal muscles, and connective tissue were sutured. Rumen motility was measured by connecting the rumen cannula to a Statham pressure transducer (Model PM6TC±1-350) by means of rubber tubing (.6 cm). The transducer was interfaced to a two-channel Houston Omniscribe recorder (Model 5231-15). Each recording was individually calibrated in centimeters of water pressure using a water manometer.

To ascertain when an eructation occurred the tracheal transection technique described by Colvin et al. (1957) was used.

After an 18- to 24-hr fast, each trial was begun by recording fasting rumen motility and eructation for 30 minutes. Following this, intrarumen pressure was raised to 10, 20 or 30 cm HOH by gas insufflation through a T-tube attached to the rumen cannula. By clamping the tubing between the anterior tracheal cannula, the mask, and the gas collecting system, no gas could be eructated; therefore, pressure could be sustained without continuous insufflation. A specific intrarumen pressure was maintained for 1 min after which the clamps were removed between the anterior tracheal cannula, the mask, and the gas collecting system. The data were gathered during deflation, that is, eructation volume and frequency and rumen motility were evaluated as intrarumen pressure returned to normal levels. Each insufflation trial required 30 minutes.

The gases used for rumen insufflation were nitrogen, compressed air, carbon dioxide-methane (60:40), and human expired air. At least 1 week was allowed between the type of gas used for rumen insufflation.

Statistical methods used in the analysis of the data are those described by Steel and Torrie (1960).

RESULTS

A typical fasting rumen motility record is shown in figure 1. The majority of the secondary contractions resulted in the eructation of a small volume of gas. During fasting, no eructations were observed to occur on a primary contraction.

The parameters determined from each record included resting intrarumen pressure and primary, secondary, and total rumen contraction frequencies. Each fasting 30-min record was divided into six 5-min periods. The data for the 5-min periods were pooled and an overall mean and standard error was calculated for each parameter. In every case at least 16 trials were considered per animal. An average resting intrarumen pressure of $-7.4 \pm 0.39$ cm HOH was observed during fasting. The average frequency of primary, secondary and total rumen contractions/5 min was found to be $2.99 \pm 0.51$, $1.03 \pm 0.38$, and $4.02 \pm 0.89$, respectively.

At least 7 trials were considered per insufflation pressure per gas per animal during the rumen insufflation experiments. A typical rumen motility record illustrating the effect of rumen insufflation to 30 cm HOH is shown in figure 2.

Figure 3A illustrates the influence on primary contraction frequency of insufflating the rumen to

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**Figure 1.** A typical fasting rumen motility record. Primary contractions are shown as $1^\circ$ and secondary contractions as $2^\circ$. 

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a resting intrarumen pressure of 10 cm HOH with the four gases. Within this pressure range there was a significant (P<.05) linear relationship between intrarumen pressure and primary rumen contraction frequency for each gas. No statistical differences were observed between slopes of the regressions due to the type of gas used for insufflation.

When the initial insufflation pressure was 20 cm HOH (figure 3B), the response of primary contraction frequency to increases in resting intrarumen pressure was similar for all four gases at resting intrarumen pressures below approximately 10 cm HOH. As resting intrarumen pressure exceeded this level, the regressions for nitrogen and compressed air diverged from carbon dioxide-methane and expired air. All regressions were significantly quadratic (P<.01).

The effect of intrarumen pressure on the frequency of primary contractions when the initial resting intrarumen pressure was 30 cm HOH is shown in figure 3C; all regressions were significantly quadratic (P<.01). The response of primary contraction frequency was similar for each gas at pressures below approximately 10 cm HOH; however, the primary contraction frequency for expired air was slightly lower than the other three gases in this pressure range. As resting intrarumen pressure exceeded 10 cm HOH, the absence of carbon dioxide in the rumen insufflation gas, that is, nitrogen and compressed air, exaggerated the divergence observed when the original insufflation pressure was 20 cm HOH.

The effect of the initial insufflation pressure, i.e., 10, 20 or 30 cm HOH, on the response of primary contractions to increasing intrarumen pressure, irrespective of the type of gas used to insufflate, is shown in figure 4. When the intrarumen pressure had decreased to less than 11 or 12 cm HOH in those trials where the initial intrarumen pressure was 20 or 30 cm HOH, the frequency of the primary contractions exceeded the frequency observed when the initial intrarumen pressure was 10 cm HOH.

Figure 5 illustrates the effect on secondary contraction frequency of insufflating the rumen to
resting intrarumen pressures of 10, 20 and 30 cm HOH with the four gases. In every case, there was a significant linear relationship (P<.01) between secondary contraction frequency and intrarumen pressure. Insufflation with nitrogen or compressed air produced similar responses and resulted in a greater secondary rumen contraction frequency than insufflation with carbon dioxide-methane or expired air at all resting intrarumen pressures tested.

The insufflation data for primary, secondary, and total rumen contraction frequency were pooled, irrespective of the initial insufflation pressure, as shown by the bottom, middle, and top pair of regressions in figure 6, respectively, with nitrogen and compressed air in one group and carbon dioxide-methane and expired air in the other. Two significant quadratic regressions (P<.01) best fit the primary contraction frequency...
Figure 6. Effect of resting intrarumen pressure on primary, secondary, and total rumen contraction frequency after rumen insufflation with either carbon dioxide-free, that is, nitrogen and compressed air (N2 - CA) or carbon dioxide-containing, that is, carbon dioxide-methane and expired air (CO2:CH4-EA) gases. The broad dashed line indicates the 95% confidence limits around the CO2:CH4-EA regressions.

Figure 6. Effect of resting intrarumen pressure on primary, secondary, and total rumen contraction frequency after rumen insufflation with either carbon dioxide-free, that is, nitrogen and compressed air (N2 - CA) or carbon dioxide-containing, that is, carbon dioxide-methane and expired air (CO2:CH4-EA) gases. The broad dashed line indicates the 95% confidence limits around the CO2:CH4-EA regressions.

Discussion

Typical rumen motility records can be divided into primary and secondary contractions. The large, backward-moving or primary contractions are concerned with the mixing of rumen contents, while eructation is associated with the smaller, forward-moving or secondary contractions. These two types of contractions can be determined readily during fasting rumen motility (figure 1). Approximately three primary and one secondary contractions occurred every 5 min during fasting; similar results have been reported by Reid (1963). Resting intrarumen pressure in the fasting animal is subatmospheric (Cole et al., 1945; Colvin and Daniels, 1965).

The difficulty in determining which is a primary and which a secondary contraction when pressure is elevated in the rumen is apparent in figure 2. It has been reported that a biphasic contraction of the reticulum usually precedes a primary rumen contraction (Wester, 1926; Reid and Cornwall, 1959; Ruckebusch and Tomov, 1973). However, it is possible for primary rumen contractions to occur independent of reticular contractions. Phillipson (1939) observed as many as four contractions of the rumen following a reticular contraction in sheep. When reticular contractions were inhibited by abomasal distension (Phillipson, 1939) or by local anesthesia (Ash and Kay, 1959) primary rumen contractions were still observed. Therefore, measuring reticular contractions does not assure accurate differentiation of primary and secondary contractions.

Ruckebusch and Tomov (1973) observed that eructation occurred on more than 98% of the secondary contractions in sheep at rest and on normal diets. Furthermore, Ruckebusch and Tomov (1973) did not observe eructation on primary rumen contractions, even during rumination when contraction frequency is greatly increased. Wester (1926) found that as a rule eructation does not accompany primary rumen contractions because the esophagus is not completely open and because gas is pressed backwards during this contraction. Although it has been reported that eructation can occur on a primary contraction (Stevens and Sellers, 1959) the evidence of others (Wester, 1926; Ruckebusch and Tomov, 1973), and our own experience indicates that this is unusual and infrequent. Therefore, by accurately measuring eructation it is possible to separate primary from secondary contractions even at elevated intrarumen pressure.

The effect of elevated intrarumen pressure on rumen motility is not as clear as one might expect, especially as concerns the influence of different gases and different pressures, despite previous experiments (Dougherty, 1942; Quin, 1943; Stevens and Sellers, 1959; Weiss, 1953; Wester, 1926). Primary contraction frequency was found to increase with resting intrarumen pressure at pressures below approximately 10 cm HOH (figure 3) and when the pressure exceeded this level, the rate was significantly inhibited. Our results provide evidence in conscious, intact animals to support the neurophysiological findings of Leek (1969) and Harding and Leek (1972a). These workers identified low threshold tension receptors in the medial walls of the reticulum and the cranial sac of the rumen which exerted an overall
that rumen insufflation with oxygen caused a more decerebrate sheep irrespective of whether 5% dioxide-methane (60:40) gas was used during observed rumen motility to be the same in carbon dioxide in oxygen, nitrogen or carbon rumen on the frequency of rumen contractions is eructation (Colvin obstacles interfering with the normal pathway of accumulated in the rumen, provided there are no that the receptors responsible for the initiation of contractions are limited. Weiss (1953) suggested that the receptors responsive specifically to carbon dioxide have been identified in the rumen at this time. Perhaps carbon dioxide exerted its effect directly on the medullary gastric centers. Ash and Dobson (1963) have established that there is a two-way exchange of carbon dioxide across the rumen epithelium, thus, providing a mechanism by which carbon dioxide could influence the gastric centers. For there to be a difference in the frequency of primary and secondary contractions caused by different insufflation gases and pressures presupposes separate centers for these types of contractions as previously suggested by the neurophysiological work of Harding and Leek (1972b). Furthermore, the evidence shown in figure 6 suggests a reciprocal relationship between these centers. When secondary contraction frequency was elevated, the frequency of primary contractions was inhibited and vice-versa. It is apparent that a maximum rumen contraction rate exists (figure 6), a rate dictated by refractory periods in the musculature of the rumen and gastric medullary center. Iggo (1956) reported that the gastric center became unexcitable for a time after eliciting rumen contractions by reflex action. Within the contraction rate limits, reciprocal innervation of the centers controlling primary and secondary contractions probably occurs.

Thus, the frequency of primary, secondary, and total rumen contractions was found to be influenced by resting intrarumen pressure and the nature of the gases used during rumen insufflation. Increases in resting intrarumen pressure resulted in a linear increase in primary contraction frequency at resting intrarumen pressures below approximately 10 cm HOH. Resting intrarumen pressures exceeding 10 cm HOH had a greater suppressing effect on primary contraction frequency when the insufflating gas contained no carbon dioxide than when carbon dioxide was present. Secondary contraction frequency was found to increase linearly with all gases and pressure levels tested. The presence of carbon dioxide in the insufflating
gas mixture resulted in a lower frequency of secondary contractions than when carbon dioxide was omitted. It appears that there is a maximum rumen contraction rate dictated by refractory periods in the gastric medullary centers and/or musculature of the rumen. In view of the findings reported in this investigation, it now becomes necessary to consider the influence on gastric medullary centers of the gases produced in the rumen, in addition to stimuli arising from rumen presso- and mechanoreceptors.

LITERATURE CITED


