Effect of Change in Body Position on Cardiopulmonary Function and Plasma Cortisol in Cattle

Masahiro TAGAWA, Shozo OKANO, Toshinori SAKO, Hiromitsu ORIMA, and Eugene P. STEFFEY

Divisions of Veterinary Surgery, 1) Veterinary Internal Medicine, 2) Veterinary Radiology, Nippon Veterinary and Animal Science University, 1-7-1 Kyonan-cho, Musashino, Tokyo 180, Japan, and 3) Department of Surgery, School of Veterinary Medicine, University of California, Davis, California 95616, U.S.A.

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ABSTRACT. The aim of these studies was to investigate the effect of body posture on circulatory and respiratory system function in unmedicated cattle. The plasma cortisol concentration was also measured and served as an indication of the level of stress imposed by animal handling and positional manipulation. Six mature, healthy Holstein cows were physically restrained and studied in standing, supine and right lateral postures. The plasma cortisol concentration increased with the change in body position. In a supine position, the value was increased to more than three times the control value ($p<0.001$). The arterial oxygen tension and oxygen saturation were significantly decreased ($p<0.001$) with changes in body position. The decrease was most pronounced when cattle were restrained in a supine position. Arterial carbon dioxide tension, heart rate, mean arterial pressure and central venous pressure did not change significantly with changes in body posture. Restraining of cattle in a lateral recumbent or supine position without introducing anesthesia was found to exert a strong stress which affected the respiratory function and increased the plasma cortisol level.—KEY WORDS: cardiopulmonary function, cattle, plasma cortisol, pulmonary shunt, stress.

Clinical examination, medical treatment and surgery in cattle are usually performed with them in a standing position. However, surgeries that require animals to be positioned in a laterally recumbent or supine position such as chest, genitai or abdominal surgery, are clinically not infrequent.

When large animals such as horses and cattle are laid down under general anesthesia, hyperpnea usually occurs and oxygenation of arterial blood becomes less efficient if respiration is not assisted [9, 11, 13, 18]. Problems almost never reported so far are those related to stress in cattle that are laid in a lateral recumbent or supine position without medication. Recently, the cardiopulmonary function of awake cattle restrained in a supine position has been studied by Klein and Fisher [12]. It has shown marked depression of PaO$_2$, PaCO$_2$ and arterial pH.

In this study, the effects of body positions on the circulatory and respiratory systems were investigated mainly to assess the intensity of stress in awake cattle kept in a standing position or restrained in a lateral recumbent or supine position.

MATERIALS AND METHODS

Test animals and experimental methods: Six healthy holstein cows without respiratory or circulatory abnormalities were studied. They ranged in age from 2 to 10 years and in weight from 390 to 510 (mean 460) kg. They were purchased as experimental animals. When delivered to our department, they were fed on concentrated feed and dry grass, and were allowed free access to water. The experiment was begun after a 24 hr fast without restricting the intake of water.

To eliminate the effect of stress due to sensitization with environmental temperature, the experiment was carried out at room temperature (18–24°C). It was carried out from 1:00 p.m. to 5:00 p.m., taking into consideration the diurnal change in the plasma cortisol concentration.

Catheterization and change in body position: Each cow has restrained in a frame. Regional anesthesia was induced by subcutaneous injection of 2% xylocaine into the neck of animals that were kept in a standing position to surgically expose the common carotid artery and jugular vein, into which catheters were inserted for measurements.

The cows were released from the frame and were left for 60 min in a standing position to stabilize their physical condition. Control values were first obtained for cardiopulmonary function and then the change of body position was begun.

A cow in a standing position was strapped to an inverted utility operating table (Fujihira Kogyo Co., Tokyo, Japan), and the body position of the cow was changed to right lateral recumbent, supine, right lateral recumbent and standing positions by maneuvering the operating table. Each position was continued for 30 min.

The animals were allowed spontaneous respiration with room air without anesthesia. No sedative or general anesthetic was used.

Measurement

(1) Heart rate, mean arterial pressure and central venous pressure

The electrocardiogram was recorded by A-B leads with electrodes attached to the body surface. Transducers for blood pressure measurement were connected to the catheters positioned in the common carotid artery and jugular vein. The blood pressure was measured and
recorded together with the ECG pattern using a patient monitoring system (Nihon Kodens, Tokyo, Japan). The positions of the transducers were changed every time the position of the body of the cow was changed, but were always set on the level of the heart.

2) Blood gases and acid-base balance

Arterial blood was anaerobically collected from the catheter indwelt in the common carotid artery with a heparinized syringe. Arterial blood pH, oxygen tension (PaO₂), and carbon dioxide tension (PaCO₂) were immediately measured with a physiologic gas analyzer (Corning, Model 158, Tokyo, Japan). Oxygen saturation (O₂sat), HCO₃⁻ and base excess (BE) were calculated from the blood gas and pH values.

3) Plasma concentration of cortisol and blood glucose level

To measure the plasma concentration of cortisol, blood was collected via the catheter indwelt in the jugular vein with a heparinized syringe. The plasma was immediately separated and stored at –80°C in a deep freezer. A radio-immunoassay kit (Eiken Immunochemical, Tokyo, Japan) was used to measure plasma cortisol. To control accuracy in measurement of plasma cortisol, the measurement was repeated. All data were obtained with standard serum added to the sample.

Jugular venous blood was also collected to determine plasma glucose. Whole blood was transferred to a test tube containing sodium fluoride and, after mixing, the plasma was immediately harvested and stored at –80°C in a deep freezer until used for measuring glucose.

Statistical analysis: The data obtained were expressed as the mean ± SD. Statistical analysis was carried out by Student t-test to compare, with the control values, the changes in blood parameters in each body position. The control values for circulatory parameters, blood gases and acid-base balance were those obtained after the passage of 60 min from the time of catheterization. The control values for plasma cortisol and blood glucose levels were those obtained in the blood samples collected from resting cattle to which no treatment was administered. Measurement of the control values for cardiopulmonary functions and plasma cortisol and plasma glucose was not performed simultaneously, because of the catheterization procedure involved.

RESULTS

Changes in heart rate, mean arterial pressure and central venous pressure: Heart rate, arterial pressure and central venous pressure did not change as body position was altered.

Changes in respiratory rate, blood gases and acid-base balance: Table 1 shows the results of respiratory system measurements. The respiratory rate did not change with changes in body position. The PaO₂ was slightly increased transiently at 30 min after taking a supine position. The lowest value for PaO₂ at 30 min after taking a supine position was 72.2±8.5 mmHg which was significantly lower (p<0.001) than the control value (98.8±7.4 mmHg). When the body position was changed to the second lateral recumbent position, PaO₂ still remained significantly low (p<0.001) until 30 min after the change to the second lateral recumbent position, although a very slight increase was recorded. The O₂sat returned almost to the control value.

The PaCO₂ tended to undergo only very slight but not significant variations with the change in body position, compared to the control value (43.2±4.3 mmHg). Arterial blood pH, HCO₃⁻ and BE were relatively stable for all body positions.

Change in plasma cortisol concentration: Figure 1 shows the changes in the plasma concentration of cortisol which was measured as an indicator of stress accompanying changes in body position. Plasma cortisol had already begun to increase, though not significantly, immediately

<table>
<thead>
<tr>
<th>Variable</th>
<th>Pre(a)</th>
<th>Stand(b)</th>
<th>Late 1(c)</th>
<th>Supine(d)</th>
<th>Late 2(e)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Respiratory frequency (breaths/min)</td>
<td>14.8±7.0⁹</td>
<td>22.2±15.4</td>
<td>19.8±13.8</td>
<td>24.7±13.7</td>
<td>20.2±13.9</td>
</tr>
<tr>
<td>pH</td>
<td>7.457±0.037</td>
<td>7.479±0.035</td>
<td>7.483±0.038</td>
<td>7.476±0.029</td>
<td>7.492±0.014</td>
</tr>
<tr>
<td>PaO₂ (mm of Hg)</td>
<td>98.8±7.4</td>
<td>106.7±28.8</td>
<td>85.3±15.3</td>
<td>72.2±8.5⁹</td>
<td>77.8±11.9⁹</td>
</tr>
<tr>
<td>PaCO₂ (mm of Hg)</td>
<td>43.3±4.3</td>
<td>42.4±3.8</td>
<td>39.5±1.5</td>
<td>39.5±4.0</td>
<td>39.9±1.4</td>
</tr>
<tr>
<td>HCO₃⁻ (mmol/l)</td>
<td>30.2±3.6</td>
<td>31.2±3.4</td>
<td>29.2±2.3</td>
<td>28.7±3.0</td>
<td>30.1±1.5</td>
</tr>
<tr>
<td>O₂Sat(%)</td>
<td>97.7±0.4</td>
<td>97.8±0.8</td>
<td>96.1±2.3</td>
<td>94.1±1.9⁹</td>
<td>95.4±1.4</td>
</tr>
<tr>
<td>B. E. (mmol/l)</td>
<td>7.0±3.7</td>
<td>7.9±3.6</td>
<td>6.6±2.7</td>
<td>6.1±2.9</td>
<td>7.6±1.6</td>
</tr>
</tbody>
</table>

a) Values are the mean±standard deviation.

b) Difference is significant (p<0.001).
c) Standing position at 60 min after insertion of the catheter.
d) Standing position at 30 min after strapping to the operating table.
e) Late 1 and 2 mean right lateral recumbent position.
f) Dorsal recumbent position.
EFFECT OF CHANGE IN BODY POSITION IN CATTLE

Fig. 1. Changes in plasma cortisol and blood glucose concentration following the change in body position in cows. The data in the figure indicate the value obtained by maintaining each position for 30 min. Values indicate the mean ± SD (n=6). * Difference is significant (p<0.001). (1) Standing position at pre-treatment (control). (2) Standing position just after the catheterization. (3) Standing position at 60 min after insertion of the catheter. (4) and (6) Right lateral recumbent position. (5) Dorsal recumbent position. (7) Standing position 30 min after the change in body position. (8) One day after the experiment.

after insertion of the catheter which was prior to changing the body position. After the stabilization of physical condition for 60 min, the value was decreased until the change in body position. With the change in body position, it gradually increased. The value immediately before changing the position to a supine position was significantly higher than (4.8 ± 2.2 μg/dl, p<0.001) the control value (1.6 ± 1.0 μg/dl). It continued to increase with the change in body position and reached a peak at 30 min after turning the animal to a supine position. It tended to decrease after changing the animal to the second lateral recumbent position. This indicated that the restrained supine position of the body exerted stronger stress on the cows than the other body positions.

Change in blood glucose: The blood glucose level tended to gradually increase with the change in body position (Fig. 1). It rose to a significantly high level (179.9% of the control value, p<0.001) in a supine position and the second lateral recumbent position. The peaking of the blood glucose level appeared after the peaking of the plasma concentration of cortisol.

DISCUSSION

It is known that when spontaneously breathing large animals such as horse and cattle are laid down under general anesthesia, the arterial blood carbon dioxide tension (PaCO₂) is increased as a result of hypoventilation. General anesthesia and recumbency also decreases the efficiency of oxygenating arterial blood and results in a large alveolar to arterial oxygen tension (PaO₂) difference [9, 11, 16, 17]. The etiology of this difference relates to marked imbalance in the distribution of ventilation relative to pulmonary blood flow (V/Q) [4, 9]. The V/Q imbalance increases in the supine position, compared to that in a lateral recumbent position, resulting in a lower PaO₂ in anesthetized animals positioned supine [17]. The effect of supination without medication on the circulatory and respiratory systems in cattle has been described by Klein and Fisher [12]. They found that PaO₂, PaCO₂ and arterial blood pH began to decrease with time from 15 min after restraint in a supine position.

This experiment was designed to investigate the effect of body position change without anesthesia on the circulatory and respiratory systems in cattle maintained on room air and the severity of stress exerted on various parts of the body, using the plasma cortisol level as an index. We obtained results that supported the finding of Klein and Fisher [12]: namely, arterial blood oxygenation was markedly decreased with the change in body position. It was found, as in a previous experiment with general anesthesia, that restraint in a supine position tended to most strongly inhibit the oxygenation of blood in the lungs and that the disturbed oxygenation tended to return to normal in the next body position. This seemed to suggest that large animals are subjected to stronger stress in a supine position than in a lateral recumbent position, as they are under general anesthesia. Thus, from the presently reported data, it seems highly likely that when large animals breathing room air without anesthesia are restrained and positioned in a lateral recumbent or supine position, hypoxemia is induced and this endangers the lives of these animals.

Plasma cortisol is known to be increased by stress induced by various factors such as physical restraint, treatment, temperature and shipment [1, 2, 5, 6, 8, 15]. The value of plasma cortisol is, therefore, significant as an indicator of the degree of stress. A persistently high level of plasma cortisol involves the risk of causing various problems, including inhibition of immunocompetence which facilitates sepsis [12, 14]. Elimination of stressors in food animals is important in an economic sense. Keeping animals free from pain, which is one form of stress, is at the same time a problem that needs to be studied in the spirit of animal protection. In this experiment, the change in body position induced a significant increase in plasma cortisol compared to the control value.

It has been reported that when plasma cortisol was
increased by endogenous cortisol or by the administration of exogenous cortisol, the blood glucose level was concomitantly increased [3]. In this experiment, the blood glucose level was examined to confirm the correlation between them. The blood glucose level was found to gradually increase with the change in body position and was significantly higher in the supine and second lateral recumbent positions than in the control value. The peaking of blood glucose appeared after the peaking of plasma cortisol. Gluco-corticoid accelerates the synthesis of glucose in the liver and inhibits the utilization of glucose in muscles, while it antagonizes the action of insulin [10]. This may be the mechanism involved in the increase in blood glucose.

In conclusion, these studies of healthy, unmedicated cattle demonstrate that restraint and lateral or supine positioning is accompanied by a significant reduction in PaO_2. General anesthesia and/or respiratory disease will likely increase the severity of the reduction in oxygen tension accompanying postural changes in cattle. Under these conditions, oxygen supplementation of inspired breath is recommended to minimize the likelihood of life threatening hypoxemia.

REFERENCES