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Studies on sodium and potassium metabolism and subsequent influence on electrocardiogram in unilaterally adrenalectomized black Bengal goat (*Capra hircus*)

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Unilateral adrenalectomy was performed in six black Bengal goat (*Capra hircus*) to study electrocardiograph in connection with mineral metabolism with special reference to sodium and potassium and some other factors of physiological importance. The parameters were studied at every 12 hrs interval upto 120 hrs and 24 hrs interval from 120 to 240 hrs. Physiological parameters, like body weight and rectal temperature, changed non-significantly ($p < 0.05$) after adrenalectomy. Among minerals, plasma sodium ($p < 0.01$) and plasma potassium ($p < 0.05$) concentration were changed significantly between hours leaving impression in ECG as widening of QRS complex and peaked T wave with increased amplitude found after unilateral adrenalectomy. Heart rate also increased significantly ($p < 0.01$) between hours.

Key words: adrenalectomy, black Bengal goat, ECG, mineral metabolism.

Introduction

All the forms of living matter require inorganic elements. Mineral elements exist in the cells and tissues of the animal body in a variety of functional chemical combinations or as enzymes and in characteristic concentrations, which vary with the different elements and tissues. Sodium and potassium are major and most important electrolytes present in body fluids being the major cations of extracellular fluid (ECF) and that of the intracellular fluid (ICF) respectively. About 89% of the total body content of potassium is within cells. Potassium maintains acid-base balance, regulation of osmotic pressure and helps in the development of cellular membrane potentials. It also influences the contractility of smooth, skeletal and cardiac muscles [18]. Electrocardiogram (ECG) can be helpful for finding electrolyte imbalances because increase in plasma potassium concentration is associated with characteristic changes in ECG [12]. Changes in fluid balance are principally responsible for changes in plasma sodium concentration. Hyponatremia is often but not invariably associated with conditions, which cause sodium depletion and resultant decrease in circulating fluid volume. These conditions are due to vomiting, diarrhoea, and excessive sweat loss and in adrenal insufficiency [9]. Adrenal gland secretes steroids from cortex and catecholamines from medulla. Cortical steroids exert their action on carbohydrates and mineral metabolism. Regulation of plasma sodium concentration and there by fluid volume is indirectly controlled by aldosterone. An approach to the study of adrenal gland function in an animal is to investigate the changes that occur in the animal after removal of the gland [5], because it plays major role in combating stress as well as to maintain the fluid balance of the animal. The effect of adrenalectomy has been studied mainly in the rat, dog, cat and to a lesser extent in the guinea pig and rabbit. Very few literatures are available to study the effect of adrenalectomy in small ruminants like goat in sub tropic region. There was no work reported on adrenalectomy in goat in Indian sub tropic region. Therefore, this study has been taken up in unilaterally adrenalectomized goat to investigate the mineral metabolism and its subsequent impact on ECG.

Materials and Methods

The study was conducted during the period from March 2003 to June 2003, temperature ranging from 23.36° to 33.5°C and humidity ranging from 62.15 to 93.82%.

Twelve female black Bengal goats (Capra hicus) were selected for this study. The ages of the animals were between 4 to 6 months and weighed between 5 to 7 kg. The animals selected were of good health with good vigor and normal behavior. The animals were kept in a dry, clean,

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well-ventilated shed with concrete floor.

Deworming of animals were carried out by using Fenbendazole (Panacure; Hoecht, India) at the dose rate of 7.5 mg/kg/body wt. Successive fecal examinations were done to ensure whether the animals remained free from endoparasites during entire course of investigations. Ivermectin (Ivomec; Indian Immunologcals, India) injection was given once to all animals (200 mg/kg/body wt) to remove external parasites from the animals. Vitamin B complex (Belamyl; Sarabhai-Zydus, India) was also given to all animals as per schedule dose.

Experimental goats were initially used for estimation of normal values of the parameters and blood samples were collected for 3 consecutive days and then subjected to operation. Blood samples were collected 24 hrs after the surgery and then 12 hrs interval to 120 hrs and then by 24 hrs interval from 120 hrs to 240 hrs.

Single stage unilateral adrenalectomy of left adrenal gland was performed in paracostal area extending dorsally upto the transverse process of the first lumber vertebra using standard surgical technique. For estimating blood volume, the dye Evan's blue (T-1824; SRL, India) was administered intravenously and eight minutes were allowed for total mixing to elapse. The blood sample was then withdrawn and the dye concentration was determined photometrically for calculation of total blood volume [8]. The level of sodium and potassium were estimated by using flame photometer (Systronics, India) [11].

ECG was recorded in the goat using 12 channel portable ECG machine (CARDIART 108 T/MK-VI; BPL, India) calibrated as 1 mV = 10 mm of amplitude and paper speed of 25 mm/sec using standard procedure [7]. amplitude (mV) and duration (msec) of P, QRS and T waves were studied in all standard bipolar leads (I, II and III) and three unipolar leads (aVR, aVL and aVF). All the numerical data were statistically analyzed by following the recommended method [14].

Results

Adrenalectomy

Among the 6 adrenalectomized goats, considered to have been operated satisfactorily, 5 animals survived except one, which died on 9th day after operation. The onset signs of adrenal insufficiency started 24 hrs after operation and proceeded upto about 72 hrs. The most marked symptoms due to adrenal insufficiency were anorexia, slight loss of weight with muscular weakness and non-significant changes in body temperature at different hours.

Body weight and rectal temperature

Weight of experimental animals were ranged between 5-7 kg with a control mean weight of 5.92 ± 0.33 kg. In the present study, adrenalectomy has got no significant effect on body weight up to 36 hrs. However, the body weight found to be slightly decreased though non-significant from 48 to 192 hrs. After operation the mean body weight at 24 and 240 hrs were 5.92 ± 0.37 kg and 6.40 ± 0.37 kg, respectively (Table 1).

The mean rectal temperature in adrenalectomized animals increased from 39.27 ± 0.08°C in control to 40.27 ± 0.15°C at 24 hrs of the operation and which gradually decreased to a mean of 39.08 ± 0.12°C at 240 hrs (Table 1).

Blood and urine volume

The mean blood volume of adrenalectomized goat showed non-significant decrease from 72.38 ± 0.84 ml/kg/body wt of control to 65.14 ± 6.44 ml/kg/body wt at 108 hrs. After 108 hrs, the blood volume gradually increased and reached to 72.55 ± 6.22 ml/kg/body wt at 144 hrs and maintained upto the end of experiment towards the control range (Table 1).

In control, the mean urine volume was 24.28 ± 0.83 ml/kg and the results obtained after adrenalectomy showed significant difference ($p < 0.05$) existing between hours. At 24 hrs after adrenalectomy it sharply rose to 28.7 ± 0.30 ml/kg at 36 hrs and then decreased to 18.08 ± 2.38 ml/kg at 84 hrs. Again it increased from 18.90 ± 2.52 ml/kg at 108 hrs and become steady to 25.74 ± 1.22 ml/kg at 144 hrs ranging control values. From 144 hrs the mean urine volume increased 31.71 ± 1.17 ml/kg at 240 hrs (Table 1).

Plasma sodium and potassium

The sodium level showed that there was a significant difference ($p < 0.01$) existing between hours. It also revealed that there was gradual decrease of mean plasma sodium level from 140.42 ± 1.70 in control to 125.50 ± 2.63 mmol/l at 36 hrs though non-significant. At 48 hrs there was a significant decrease (117.50 ± 2.7 mmol/l) in plasma sodium concentration. At 60 hrs mean plasma sodium concentration was 120.17 ± 5.32 mmol/l, gradually increased upto 144 hrs to a level of 140.17 ± 3.51 mmol/l and again decreased to 130 ± 3.44 mmol/l at 192 hrs and continued upto the end of experimental period. From control to 24 hrs after surgery the mean plasma sodium concentration was maintained at same level (Table 1).

Plasma potassium level showed significant ($p < 0.05$) difference between hours. There was a significant increase in mean plasma potassium from the control value of 5.04 ± 0.50 to 6.57 ± 0.28 mmol/l at 24 hrs. From 36 to 48 hrs it decreased to a level of 5.81 ± 0.36 mmol/l At 60 hrs it again increased to the level of 6.14 ± 0.19 mmol/l which was non significant compared to control value. From 84 hrs it reached the level of 5.53 ± 0.27 mmol/l and gradually reached the control level, 5.23 ± 0.32 mmol/l at 144 hrs and then increased to 6.20 ± 0.17 mmol/l at 216 hrs (Table 1).

Heart rate

The heart rate differed significantly ($p < 0.01$) between

Table 1. Physical characteristics, blood and urine volume, plasma sodium and potassium concentration and heart rate of pre- and post unilaterally adrenalectomized black Bengal goat (mean ± SE)

Parameter(unit)	Control	24	36	48	60	72	84	96	108	120	144	168	192	216	240 hr
Body weight (BW, kg)	5.92 ±0.33	5.92 ±0.37	5.90 ±0.37	5.89 ±0.38	5.73 ±0.36	5.78 ±0.35	5.78 ±0.35	5.82 ±0.34	5.76 ±0.51	5.78 ±0.51	5.82 ±0.58	5.83 ±0.56	5.88 ±0.57	5.90 ±0.57	6.40 ±0.37
Rectal temperature (°C)	39.27 ±0.08	40.27 ±0.15	39.23 ±0.26	39.62 ±0.25	39.28 ±0.07	39.33 ±0.13	39.33 ±0.13	39.21 ±0.21	39.18 ±0.25	39.37 ±0.25	39.40 ±0.15	39.13 ±0.29	39.25 ±0.28	39.27 ±0.13	39.08 ±0.12
Blood volume (ml/kg/BW)	72.38 ±0.84	87.42 ±7.15	76.67 ±9.30	*	73.39 ±7.92	*	66.48 ±6.83	*	65.14 ±6.44	*	72.55 ±6.22	69.92 ±3.50	69.79 ±6.20	71.49 ±5.20	72.56 ±2.05
Urine volume† (ml/kg/BW)	24.28^{ab} ±0.83	*	28.70^{ab} ±0.30	*	19.97^{a} ±1.59	*	18.08^{a} ±2.38	*	18.90^{a} ±2.52	*	25.74^{ab} ±1.22	27.45^{ab} ±1.09	26.48^{ab} ±0.66	30.94^{b} ±1.05	31.71^{b} ±1.17
Plasma sodium‡ (mmol/l)	140.42^{a} ±1.70	139.42^{ac} ±1.28	125.50^{ab} ±2.63	117.50^{b} ±2.70	120.17^{bd} ±5.32	121.33^{bd} ±2.09	122.00^{bd} ±6.78	125.00^{bc} ±3.25	128.17^{abc} ±5.07	132.17^{abc} ±3.52	140.17^{abc} ±3.51	138.33^{a} ±2.86	130.00^{abc} ±3.44	130.17^{abc} ±4.74	130.80^{abc} ±6.95
Plasma potassium§ (mmol/l)	5.04^{acef} ±0.50	6.57^{b} ±0.28	5.57^{adef} ±0.23	5.81^{acdf} ±0.36	6.14^{bcfg} ±0.19	5.59^{def} ±0.27	5.53^{adef} ±0.27	5.32^{ade} ±0.18	5.28^{ac} ±1.60	5.38^{acde} ±0.33	5.23^{e} ±0.32	5.32^{ac} ±0.27	5.96^{fg} ±0.35	6.20^{bg} ±0.17	*
Heart rate¶ (beats/min)	107.17^{a} ±1.36	150.50^{b} ±4.33	*	*	*	*	*	*	*	125.17^{c} ±3.01	*	*	107.17^{a} ±2.20	*	125.33^{c} ±3.60

*Asterisk means that the record was not taken.
Superscript alphabet $^{(a-g)}$ means that it does not differ significantly in the same row.
P-value is as follows, respectively.
† $p < 0.05$, ‡ $p < 0.01$, § $p < 0.05$, ¶ $p < 0.01$.

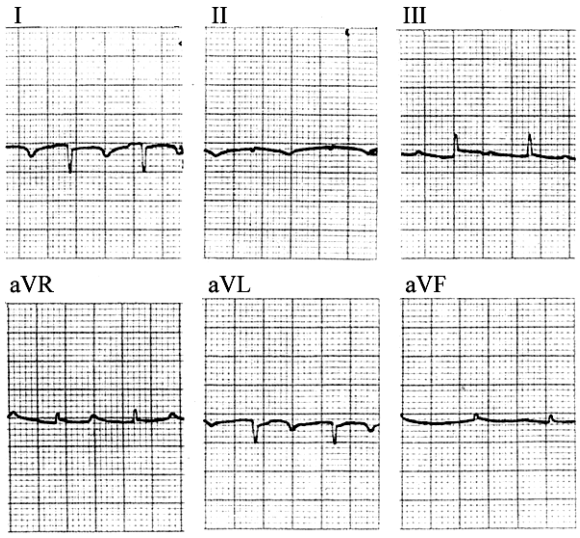

Fig. 1. Normal electrocardiogram of black Bengal goat.

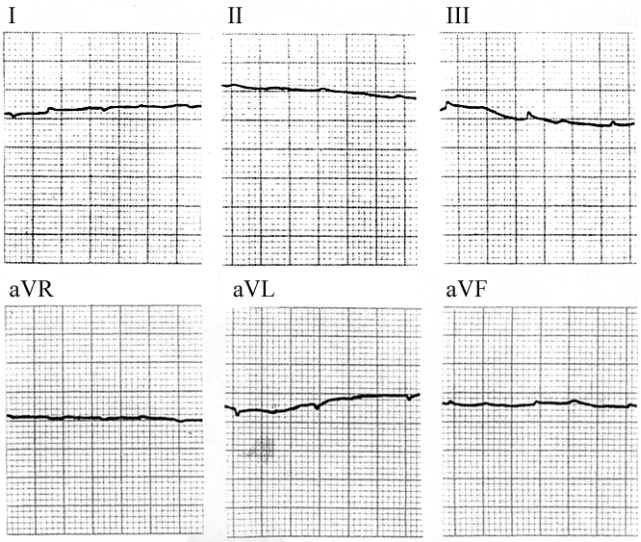

Fig. 2. Electrocardiogram of black Bengal goat after day 12 of unilateral adrenalectomy.

hours. Heart rate was calculated from ECG tracings. In control, heart rate was 107.17 ± 1.36 beats/min. In the present study there was increase of mean heart rate after 24 hrs of operation and found to be 150 ± 4.33 beats/min and subsequent finding at 120 hrs was 125.17 ± 3.01 beats/min which was higher than the control value. The heart rate subsequently reduced to 107.17 ± 2.20 beats/min at 192 hrs and increased to 125.33 ± 3.60 beats/min at 240 hrs (Table 1).

Electrocardiographic waves

The ECG of control (Fig. 1) and adrenalectomized animals (Fig. 2 & 3) were examined for studying P wave, QRS complex and T wave at various intervals (24, 120, 192 & 240 hrs) and compared. Changes in ECG properties marked with distinct depression or absence of P wave, widening of QRS complex, sharp or 'tented' T waves and slight arrhythmia were clearly visible in L-II, L-III and aVL.

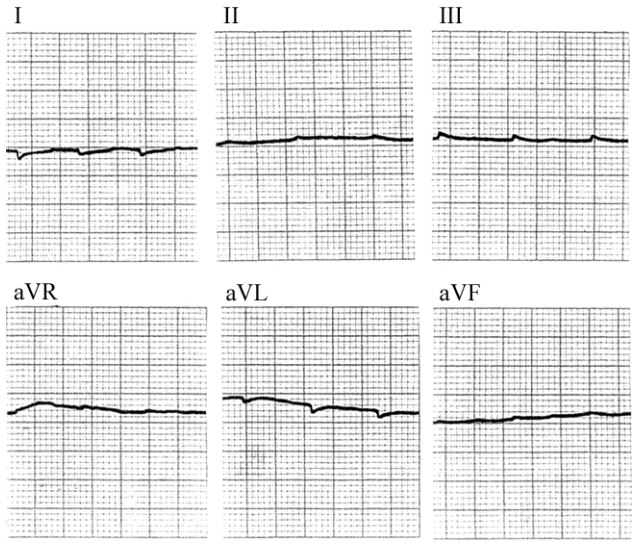

Fig. 3. Electrocardiogram of black Bengal goat after day 16 of unilateral adrenalectomy.

Discussion

The symptoms observed after adrenalectomy started from 24 hrs to 72 hrs are classically supported [1]. The alleviation from these symptoms after 72 hrs may be due to compensatory mechanism by other un-operated adrenal gland.

The main factor, which may be contributing to the slight decrease in body weight as evidenced from the experimental animals may be due to the surgical stress. The feed intake reduced to a great extent along with water consumption. This could play a major impact on body weight. Literature being scanty on body weight and adrenalectomy but anorexia is one of the major factors for decrease in body weight of animals after adrenalectomy [1].

The increase in temperature upto 24 hrs may be due to the inflammatory process and surgical trauma involved in the adrenalectomy. The decrease in temperature was probably due to post-operative antibiotic therapy with subsequent fall of interleukin-1 secreted from leukocytes. As cortisol was known as best potent anti-inflammatory agent, the desired level of cortisol being maintained by existing adrenal gland at later stage which brings back the temperature to normal level [1].

Due to deficiency of aldosterone after adrenalectomy, fluid balance is not maintained and since blood is the major fluid component of the body its level is reduced due to decrease of plasma volume during aldosterone deficiency [8]. The reduction in blood volume results from loss of water from plasma as in severe dehydration [1]. This

dehydration was primarily due to failure to retain body water as a result of sodium diuresis and partly due to intra cellular movements of water during aldosterone deficiency [13]. Although the level of blood volume showed rising trend after 144 hrs towards the control level and maintain upto the end of the experimental period, such increase in blood volume may be due to the hyperactivity of the existing adrenal gland compensating the decrease level of aldosterone.

The rise of urine volume at 36 hrs was partially due to normal saline given to the animal after adrenalectomy and partially due to *ad libitum* water taken after fasting. The significant decrease in urine volume from 60 to 108 hrs may be due to the adrenalectomy. This finding coincided with results where there was a decreased urine volume in adrenalectomized rats [10]. From 144 hrs the mean urine volume increased to its control value due to the restoration of fluid balance in the body.

The significant decrease in the plasma sodium concentration after 24 hrs may be due to unilateral adrenalectomy [3,5]. The declining trend in sodium level might be due to decrement of aldosterone level leading to excretion of more sodium through distal convoluted tubules of kidney [15]. The plasma sodium reaches its control level by 144 hrs. It is probably due to the compensatory mechanism imparted by the existing gland.

The sharp rise in potassium level at 24 hrs interval may be due to adrenalectomy [4] and also depicted in ECG as depressed P wave, wide QRS and tented T wave, which are the classical electrocardiographic changes in hyperkalemia. As there was a decrease in aldosterone level, sodium diuresis comes into act resulting increased potassium level to compensate loss of cation. Secretion of aldosterone from the adrenal cortex was sensitive to ECF potassium, so small rise of potassium caused increase in aldosterone secretion and thereby raises the potassium level at 24 hrs. The plasma potassium concentration gradually reached to its control value by 144 hrs is probably due to the compensatory mechanism imparted by the existing adrenal gland.

The increase of heart rate [19] at 24 hrs from control may be due to surgical shock viz., loss of blood causing hypotension, fever and hyperkalemia, which trigger the tachycardia [20]. Again the further decrease of heart rate at 192 hrs towards control value, which is maintained to the end of the experiment may be due to stabilization of normal physiological system. As there was no such literature at present, it could not be compared.

The prominent decrease of amplitude of P wave, widening of QRS complex and peaked or tented T wave in adrenalectomized goat may be due to the effect of hyperkalemia.

The increased extracellular potassium concentration imparts two major changes in transmembrane action potential (TAP) of cardiac cell. Elevated potassium concentration of ECF increases membrane permeability to potassium [16] thereby increasing the rate of repolarization and shortening of the duration of the TAP. These changes in TAP characteristics are responsible for the electrocardiographic manifestation of hyperkalemia. The earliest electrocardiographic changes in hyperkalemia are peaked or 'tented' T waves in L-II and L-III and our findings are in agreement with other workers [2]. The peaked or 'tented' T- waves may be due to the shortening of TAP. The widening of QRS complex (>0.04 sec) in bipolar leads occurs when extra cellular potassium increases. Consequently the transmembrane diastolic potassium gradient is reduced causing decreased resting membrane potential (RMP) and in turn slows the intraventricular conduction [6]. Depressed or absence of P-waves as found may be due to the reduction of intraatrial conduction. The effect of hyperkalemia on cardiac rhythms is complex and virtually any arrhythmia may be occurred. Ventricular arrhythmia or cardiac arrest was more in hyperkalemia [10]. Slight and non-significant arrhythmia is probably due to impaired AV conduction resulting from slow elevation of potassium [17].

In this present study, unilateral adrenalectomy and effect on sodium and potassium have been studied along with some other physiological parameters. Adrenal gland serves as one of the major endocrine organs in black Bengal goat with wide range of physiological action and mineral metabolism like sodium and potassium, responsible for combating stressful condition in these animals along with homoeostasis and thereby survival of animals.

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References

1. **Braezile JE.** Textbook of Veterinary Physiology. pp. 282-512, Lea & Febiger, Philadelphia, 1971.
2. **Braun HA, Surawicz B, Bellet S.** T wave in hyperpotassemia. Am J Med Sci 1955, **230**, 147-156
3. **Cowie AT, Stewart J.** Adrenalectomy in goat and its effects on the chemical constituents of blood. J Endocrinol 1949, **6**, 197-204.
4. **Cowie AT, Tindal JS.** Adrenalectomy in goat. Replacement therapy and maintanance of lactation. J Endocrinol 1958, **16**, 403-414.
5. **Estergreen VL, Van Demark NL.** Adrenalectomy of the calf and its effects on various blood constituents. J Dairy Sci 1961, **44**, 928-936.
6. **Fisch C, Feigenbaum H, Bowers JA.** The effect of potassium on atrioventricular conduction of normal dogs.

Am J Cardiol 1963, **11**, 487- 492.
7. **Jafrin AH.** Comparative electrocardiography in domestic animals with special reference to cardiac axis in goat. M.V.Sc thesis, West Bengal University of Animal and Fishery Sciences, Belgachia, Kolkata, 2002.
8. **Jain NC.** Schalm's Veterinary Haematology. 4th ed. pp. 87-102, pp. 225-339, Lea & Febiger, Philadelphia, 1986.
9. **Kaneko JJ, Harvey JW, Bruss ML.** Clinical Biochemistry of Domestic Animals, 5th ed. pp. 485-516, Academic Press, New York, 1997.
10. **Kenyon CJ, Saccoccio NA, Morris DJ.** Aldosterone effects on water and electrolyte metabolism. J Endocrinol 1984, **100**, 93-100
11. **Marti B, Munoz R.** Manual of Flame Photometer. p. 1236, American Elsevier, New York, 1957.
12. **O'Dell BL, Sunde RA.** Handbook of Essential Mineral Elements. pp.153-183, Marcel Dekker, New York, 1997.
13. **Reece WO.** Fluid volume changes associated with withdrawal and restoration of steroid therapy in adrenalectomized dogs. Am J Vet Res 1972, **33**, 1493-1498.
14. **Snedecor GW, Cochran WG.** Statistical Methods. 7th ed. pp. 156-236, Oliver & Boyd, Edinburgh, 1967.
15. **Sreemanarayanan O, Phillips GD.** Bilateral adrenalectomy in sheep and its effects in certain constituents on blood. Livestock Advisor 1990, **15**, 19-22.
16. **Surawicz B.** Relationship between electrocardiogram and electrolytes. Am Heart J 1967, **73**, 814-834
17. **Surawicz B.** The interrelationship of electrolyte abnormalities and arrhythmias. In: Mandal WS (ed). Cardiac Arrhythmias: Their Mechanism, Diagnosis and Management. pp. 83-106, Lippincott, Philadelphia, 1980.
18. **Swenson MS, Reece O.** Dukes Physiology of Domestic Animals. 11th ed. pp. 9-21, Panima, New Delhi, 1996.
19. **Upadhyay RC, Sud SC.** Electrocardiogram of goat. Indian J Exp Biol , 1977, **15**, 359-362.
20. **Vassalle M.** Cardiac pacemaker potentials at different extra- and intracellular K concentration. Am J Physiol 1965, **208**, 770-775.