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The clinical implication of sodium-potassium ratios in dogs

Son-Il Pak

Department of Internal Medicine, College of Veterinary Medicine, Seoul National University, Seoul 151-742, Korea

Although there have been substantial evidences on the usefulness of electrolytes for the diagnosis of disease, the evidences for a direct link between serum sodium and serum potassium in relation to a specific disease are very limited. This study was performed to investigate an association between diseases and Na:K ratios in dogs. From January 1997 to December 1999, a total of 39 cases with an Na:K ratio less than 27 were retrieved from the medical records of Veterinary Medical Teaching Hospital, Seoul National University. Ten dogs (25.6%) had a renal or urinary disease, and six (15.4%) had a parasitism. Other miscellaneous diseases included deep pyoderma, grade III patellar luxation, bacterial pneumonia, diabetes, pancreatitis, and pyometra. The Na:K ratio was significantly lower in dogs with renal failures than those with parasitic diseases (p=0.0735). With the criterion of the Na:K ratio < 27, twenty seven dogs (69.2%) had hyperkalemia, whereas thirteen dogs (33.3%) had hyponatremia. Of 13 dogs with Na:K ratios between 20 and 24, six were diagnosed as a renal or urinary tract disease, two as diabetes, and two as a parasitism. The Na:K ratios of 9 dogs were < 20, being with the most prevalent with the disease of renal failures (55.6%). The serum Na:K ratios were more closely related to serum potassium concentrations (γ= –0.8710) than serum sodium concentrations (γ=0.4703). Two dogs with diabetes had an electrolyte pattern of hyperkalemia with normonatremia. Further studies are needed to determine the usefulness of Na:K ratio for diagnosis of hypoadrenocorticism, and to establish a relationship between patellar luxation and electrolyte unbalance.

Key words: dog, electrolyte, sodium-potassium ratio

Introduction

Sodium is a principal cation in the extracellular fluid and one of the essential mineral elements. Dietary deficiency of sodium has been associated with decreased production and lower fertility in large ruminants [20]. Normal plasma sodium and potassium concentrations are maintained by balanced intake and excretion, intracellular and extracellular osmotic pressure, and pH [2]. Sodium-potassium (Na:K) ratio has frequently been used as a diagnostic tool to identify adrenal insufficiency. The normal Na:K ratios in dogs range from 27:1 to 40:1, while the values in canine hypoadrenocorticism (Addison's disease) are often below 27:1 and may be below 20:1 in primary [6, 14, 22, 23, 25]. However, other disorders including renal failures, gastrointestinal diseases (parasitism, gastric torsion, malabsorption syndrome, and perforated ulcers), and acidosis can also cause similar electrolyte disturbances classically associated with primary hypoadrenocorticism characterized by hyponatremia and hyperkalemia [4, 11, 33].

There are substantial evidences on the usefulness of electrolytes for the diagnosis of diseases, but the direct evidences for a link between serum sodium and potassium concentrations and a disease are very limited. In a study [27] researchers have reported hyponatremia with normokalemia as a more frequent cause of low Na:K ratios, but other study [25] showed that hyperkalemia was consistently present in dogs with Na:K ratios < 27, and hyponatremia was much less consistent.

The profiles of serum electrolyte concentrations may provide diagnostic information on clinical decision-making in some diseases. Traditionally, the differential diagnosis of electrolyte disorders has been framed in terms of pathophysiology, and the analysis of clinical problems has usually proceeded in the same way. Clinicians who encounter dogs with serious electrolyte abnormalities have been tried to develop a rapid-response laboratory analysis to establish the association between diseases and electro lyte balances. The objective of the study was to determine frequent causes decreasing the Na:K ratio in canine patients. Some diseases potentially related to the electrolytes are reviewed.

*Corresponding author
Phone: 82-2-880-8685; Fax: 82-2-875-5585;
E-mail: paksi@hanimail.com

Materials and Methods

Criteria and collection of data

From January 1997 to December 1999, a total of 39 dogs with Na:K ratios less than 27 were retrieved from the medical records of Veterinary Medical Teaching Hospital, Seoul National University. Subsequently, the medical records were reviewed and the primary diagnoses were recorded. Other information gathered from the medical records included signalment, clinical signs on admission and historical findings, physical examination findings, results of biochemical analyses, information on concurrent diseases, and outcome. In the case of hypoadrenocorticism, a combination of clinical signs, clinical chemistry profiles, and the value of an adrenocorticotropin (ACTH) stimu- lation test was used for the diagnosis.

Statistical analysis

In each case, the serum sodium concentration and the potassium concentration were compared its respective Na:K ratio using a method for calculation of the coefficient of correlation (γ). The closer the absolute γ value is to 1, the greater the correlation between two values [3]. The significance of Na:K dif- ference between groups of renal failures and parasitic diseases was analyzed by the Mann-Whitney U-test at the level of $P<0.1$. Data analyses were done with a statistical package (release 6.12; SAS Institute, Cary, NC, USA) [28] and the MedCalc software (ver 4.30 for windows, Med- Calc, Belgium) [15].

Results

Of 68 records retrieved, twenty-nine were excluded because either their medical records were not sufficient to analyze or the final diagnosis was not specific. Table 1 shows the values of serum sodium and potassium concentrations, the Na:K ratios, and the primary diagnosis for each case. Ten dogs (25.6%) were diagnosed as a renal failure including acute nephritis, 6 dogs (15.4%) as parasitic or protozoal diseases (e.g., *Trichuris* spp, *Toxocara canis*, ascariasis and giardiasis), three (7.7%) as deep pyoderma, two as grade III patellar luxation, 2 as bacterial pneumonia, 2 as diabetes, 2 as pancreatitis, and 2 as pyometra. The other diseases included heart failure, hypoadrenocorticism, abdominal multiple bite wound, portosystemic shunt, tarsal and metatarsal necrosis, urinary bladder and urethral mineralization, hindlimb paralysis, heartworm infection, preputal inflammation, and steroid-induced hepatopathy each.

Of 13 dogs with Na:K ratios between 20 and 24, six were diagnosed as a renal or urinary tract disease, two as diabetes, and two as a parasitism. The remaining 3 dogs in this group had miscellaneous diagnoses that included pyometra, deep pyoderma, and bacterial pneumonia. Of 9 dogs with Na:K ratios < 20, five dogs (55.6%) had renal failure, of which 3 dogs were died right after admission. Other miscellaneous diseases included severe parasitism (ascariasis and trichuriasis), deep pyoderma, pyometra, and hypoadrenocorticism. Of 39 dogs with a Na:K ratio of

Table 1. Diagnosis listed in descending order of Na:K ratio values and its respective concentrations (mEq/L) of serum sodium and potassium

Sodium*	Potassium#	Na:K ratio	Primary diagnosis
132	4.9	26.94	pancreatitis
150	5.7	26.32	patellar luxation
147	5.6	26.25	pancreatitis
152	5.8	26.21	bacterial pneumonia
146	5.6	26.07	patellar luxation
145	5.6	25.89	abdominal multiple bite wound
137	5.3	25.85	parasitism
139	5.4	25.74	parasitism
149	5.8	25.69	parasitism
150	5.9	25.42	portosystemic shunt
144	5.7	25.26	renal failure
150	6.0	25.00	heartworm infection
150	6.0	25.00	tarsal & metatarsal necrosis
149	6.0	24.83	steroid-induced hepatopathy
140	5.7	24.56	heart failure
152	6.3	24.13	hindlimb paralysis
147	6.1	24.10	preputal inflammation
163	6.8	23.97	urinary bladder & urethra mineralization
148	6.2	23.87	parasitism
107	4.5	23.78	bacterial pneumonia
152	6.4	23.75	pyoderma
140	6.0	23.33	renal failure
146	6.3	23.17	pyometra
148	6.4	23.13	diabetes
140	6.1	22.95	parasitism
150	6.9	21.74	diabetes
143	6.6	21.67	acute nephritis, renal failure
138	6.4	21.56	renal failure
125	5.9	21.19	renal failure
137	6.5	21.08	renal failure
142	7.2	19.72	renal failure
132	6.7	19.70	pyometra
134	7.8	17.18	renal failure
127	7.4	17.16	renal failure
155	9.2	16.85	renal failure
122	7.3	16.71	renal failure
126	8.0	15.75	hypoadrenocorticism, renal failure
112	7.7	14.55	parasitism
143	10.0	14.30	pyoderma

*Reference range=140-152 mEq/L; #Reference range=3.6-5.8 mEq/L [32].

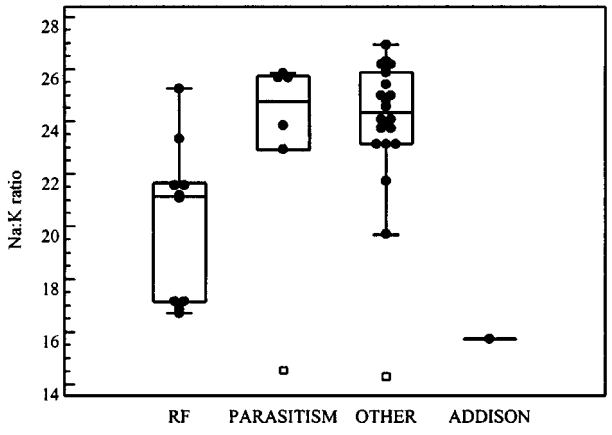

Fig. 1. A box-plot of some selected disorders evaluated using Na:K ratios. The lower line of the box represents the 25th percentile, the upper line of the box the 75th percentile, and the line within the box the median. RF = renal failure. ADDISON = Addison's disease.

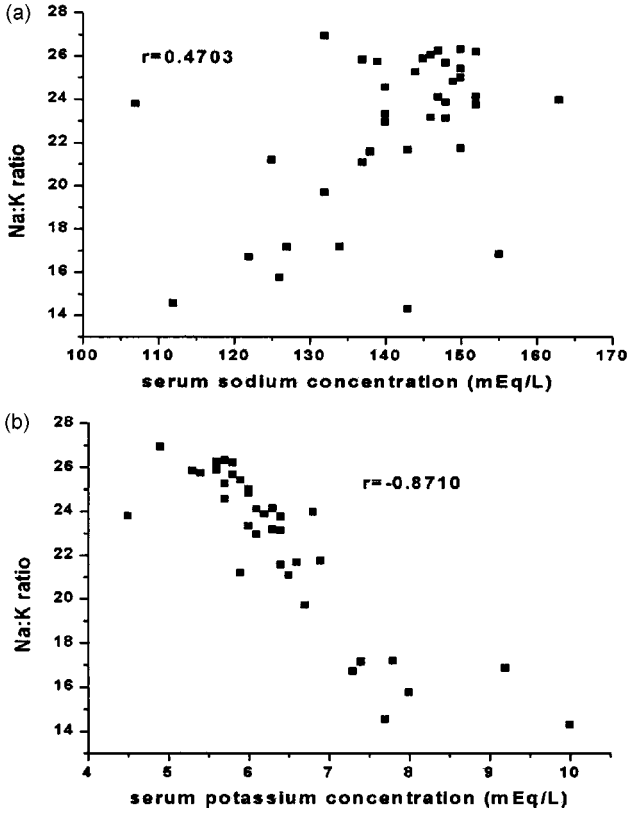

Fig. 2. The relationship between serum Na:K ratio and serum sodium (a) and potassium (b) concentration (mEq/L) in 39 dogs with an Na:K ratio less than 27.

< 27, twenty seven dogs (69.2%) had hyperkalemia, whereas thirteen dogs (33.3%) had hyponatremia.

A box-plot of some selected diseases is presented in Figure 1. The Na:K ratio was significantly lower in dogs with renal failures than those with parasitic diseases (z=1.7897; p=0.0735). Figure 2 shows the relationship between the serum Na:K ratio and the serum sodium or potassium concentration. The serum Na:K ratios were more closely related to serum potassium concentrations (γ=–0.8710) than serum sodium concentrations (γ= 0.4703). Given the guidelines for interpreting γ values, the correlation between the serum potassium concentrations and the Na:K ratios was interpreted as excellent and the correlation between the serum sodium concentrations and the Na:K ratios was interpreted as fair.

Discussion

The severe volume depletion generally reflects underlying loss of sodium. Any condition which interferes with the release of antidiuretic hormone (ADH) or the ability of the kidney to produce concentrated urine can greatly increase some nutrient losses, resulting in potassium depletion, hypercalcemia, pyometra, inadequate protein uptake by reducing urea production, and Cushing's syndrome [17]. Hyponatremia is primarily associated with renal sodium wasting and water retention due to an inability to excrete ingested water. The latter may be due to the persistent secretion of ADH, although free water excretion can also be limited in some disorders like renal failure and primary polydipsia in which the ADH levels may be appropriately suppressed. Because the loss of sodium by the kidney is accompanied with loss of water, the hyponatremic patient often becomes severely dehydrated if fluid intake does not compensate for urinary losses [31].

Serum potassium, the major cation in the intracellular fluid, is normally maintained within a narrow range through an exquisite balance mechanism between cellular potassium efflux and influx. Hyperkalemia may result from both a shift of the ion from the intracellular to the extracellular compartment and a decrease in the renal excretion of potassium. The former may be due to loss of the effects of cortisol upon the sodium-potassium pump, which normally maintains a potassium gradient across the cellular membrane [29]. It is particularly important that the signs and symptoms of changes in plasma potassium concentrations should be particularly recognised and quickly treated, because the changes are potentially life-threatening.

Hypoadrenocorticism is common in dogs with Na:K ratios less than 25 [16, 23]. Sadek *et al.* [27] reported that all cases except one had a normal Na:K ratio greater than 27:1. In some studies, serum biochemical testing often revealed hyperkalemia, hyponatremia, hyperphosphatemia, hypercalcemia, and azotemia [12, 14], but not in other studies [22, 27]. An abnormal sodium-potassium ratio is not pathognomonic for hypoadrenocorticism. Diseases associated with severe sodium depletion can cause the ratio to become subnormal, whereas diseases associated

with hyperkalemia also produce Na:K ratios of < 27:1, thereby causing a misdiagnosis as hypoadrenocorticism [31]. In the present study, only one dog with hypoadrenocorticism had a value of 15.75. Further studies are needed to determine the usefulness of Na:K ratio for diagnosis of the disease.

The common diseases associated with hyperkalemia other than hypoadrenocorticism include acute oliguric or anuric renal failures and severe gastrointestinal disorders. In this study, renal or urinary tract diseases (47.6%, 10/21) were the most common cause for the Na:K ratios of < 24. This finding was similar to the result of the previous study [25]. Also if the ratio was markedly decreased to < 20, a renal or urinary tract disease was the common case. Diabetes mellitus causes hyperkalemia both through acidosis and the reduced levels of insulin available to promote cellular uptake of potassium [1, 5]. In this study, two dogs with the Na:K ratios of 21.74 and 23.13, respectively were identified, in which both cases had an electrolyte pattern of hyperkalemia with normonatremia.

Naturally occuring hyperadrenocorticism (Cushing's syndrome) is an extremely common and well-recognised endocrine disorder in dogs, with an incidence far greater than that in humans [7]. Although hypokalemia [18, 24, 30], hypernatremia with hypokalemia [21] has been recognized in some dogs, serum electrolytes of sodium, potassium, and chloride are usually within normal limits.

In this study, the comparison of the Na:K ratios to serum sodium concentrations and to serum potassium concentrations revealed that the low Na:K ratios were more strongly correlated with increased serum potassium concentrations than with decreased serum sodium concentration. Of 39 dogs with the Na:K ratios of < 27, 27 dogs were hyperkalemia (69.2%), whereas 13 dogs were hyponatremia (33.3%). This finding differs from the results of the previous study [27], in which the low Na:K ratios were more often associated with hyponatremia and normokalemic. However, our results were similar to the report from others [25].

Sodium and potassium are also the major cations found in the pancreatic fluid at the concentrations similar to the extracellular fluid levels. Although most cases with pancreatitis initially have serum sodium, chloride, and potassium levels within normal limits, various serum biochemical abnormalities are identified, including hypoglycemia, pypercalcemia, azotemia and other electrolyte abnormalities, hypoalbuminemia, hypercholesterolemia, and lipemia [9, 26]. The Na:K ratios of 22.81 and 20.51 have been previously reported in two dogs with pancreatitis [25]. Two dogs with pancreatic disorders was also documented in the present study.

There are few studies on the relationship between joint luxation and electrolyte unbalance. Hip dysplasia has a primarily hereditary basis, but in addition to this, environmental factors have been reported to contribute to the variation in phenotypic expression [8, 13]. In 1983, Olsewski *et al.* [19] proposed a concept that synovial fluid volume, as related to osmolarity, has been postulated to be associated with the pathogenesis of hip dysplasia. In 1993, Kealy *et al.* [10] reported the relationship between dietary anion gap (DAG) and hip dysplasia. The low DAG resulted in less coxofemoral joint laxity and less hip dysplasia in growing dogs. In this study, two dogs in this category are not enough statistically to drive a correlation between patellar luxation and electrolyte unbalance.

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