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URINE SPECIFIC GRAVITY-THE MOST UNDERUTILIZED TEST IN VETERINARY MEDICINE

Determining urine specific gravity is essential to localize azotemia, diagnose kidney failure (CKD), verify and localize the cause of polyuria, accurately interpret every urinalysis result, accurately interpret many serum biochemical values, ensure effective management of the acutely ill patient, and verify compliance of administration of several prescription foods and medications. Although urine specific gravity is a simple, easy, rapid, and inexpensive test to perform it is often overlooked or not requested until a time when its interpretation is confounded by treatment (i.e. after fluid therapy or medications that alter urine concentrating mechanisms) even though it is most useful when measured prior to therapy.

The kidneys play a fundamental role in tightly regulating plasma volume and composition to maintain osmolality despite fluctuations in fluid consumption, diet and disease. Regulation of water and solutes is the result of careful adjustments in glomerular filtration, tubular reabsorption, and tubular secretion. Measurement of urine osmolarity directly by osmometry or indirectly by urine specific gravity is the primary method used to evaluate the kidney's response (i.e. concentration-removing water in excess of solute, or dilution-removing solute in excess of water) to the water needs of the body. Thus, evaluation of urine osmolarity or specific gravity is an index of tubular reabsorption of water in relation to solutes.

Increased thirst and urine production are common owner concerns. Knowledge of specific gravity is essential to verify polyuria and to differentiate its underlying causes (table 1). Another essential indication for routine evaluation of urine specific gravity involves interpretation of tests that are part of the complete urinalysis. Specific gravity is also used as an aid to monitor the patient's fluid balance, especially during need for therapy with parenteral fluids. Most importantly urine specific gravity is used to localize azotemia and differentiate primary renal failure (table 2) from other polyuric disorders.

Glossary of Common Terms

Normal Urine specific gravity
The specific gravity of normal animals is variable, being dependent on the fluid and electrolyte balance of the body, the protein, mineral and water composition of the diet, and other variables related to the species and individual. Urine specific gravity typically fluctuates widely from day to day and within the same day. A typical normal range for the dog is 1.001 to 1.060 in dogs and 1.001 to 1.080 in cats. Depending on the requirements of the body for water and/or other solutes, any specific gravity value within this range may be normal. Therefore, the concept of an average normal specific gravity is misleading because it implies that values below or above the average may be abnormal.

Concentrated Urine
Urine is concentrated if it is significantly above the specific gravity of glomerular filtrate (greater than 1.008 to 1.012). The ability of patients to excrete concentrated urine is dependent on 1) a functional nervous system for production and release of antidiuretic hormone, 2) a sufficient number of nephrons to generate and maintain a high solute concentration in the renal medulla, and 3) a sufficient population of functioning tubules to respond to antidiuretic hormone. Data from partially nephrectomized dogs suggest that only about 1/3 of the nephrons of both kidneys is required to concentration urine to 1.030 or greater.

Dilute urine
Urine is dilute if it is significantly below the specific gravity of glomerular filtrate (less than 1.008 to 1.012). Metabolic work is required to dilute glomerular filtrate by removing solutes in excess of water. Therefore, a urine specific gravity below 1.008 indicates that a sufficient number of functioning nephrons (commonly estimated to be at least 1/3 of the total population, but urine dilution occurs even if functioning kidney mass is less than 1/3) are present to dilute urine, and therefore prevent the clinical signs associated with primary renal failure. Dilution is an appropriate and expected clinical response to over-hydration. However, formation of dilute urine when the patient is in negative water balance is abnormal and is usually an indication of the inability of

antidiuretic hormone to stimulate receptors on distal renal tubules and collecting ducts (necessary to assemble water channels; examples include hypokalemia, hypercalcemia, urinary obstruction, nephrogenic diabetes insipidus), inability of the kidneys to generate a hyperosmotic medullary interstitium (recall that water only moves passively and needs a osmotic gradient; examples include kidney failure, hypoadrenocorticism, loop diuretics, decreased urea production), osmotic diuresis (diabetes mellitus and glucosuria, kidney failure and postobstructive diuresis), and lack of antidiuretic hormone (for example central diabetes insipidus).

Hypersthenuria
Urine specific gravity much greater than that of glomerular filtrate (i.e. greater than 1.008 to 1.012). These values are often >1.030 in dogs and >1.035 in cats.

Hyposthenuria
Urine specific gravity that is less than glomerular filtrate (i.e. less than 1.008 to 1.012)

Isosthenuria
Urine specific gravity greater that is similar to glomerular filtrate (i.e. 1.008 to 1.012)
Inappropriate urine concentration
Urine specific gravity that is inappropriately low (i.e. below 1.030 in dogs and below 1.035 in cats) in patients that are dehydrated or azotemic that are not receiving drugs or other therapy, which may prevent or interfere with urine concentration mechanisms.

A better Method of Classifying Urine Concentration
As clinicians, we often refer to values being within or outside of the normal range. However, this is not possible with the urine specific gravity (and many of the other values of the urinalysis). Why? Because kidneys function to maintain plasma osmolality within a very narrow range. They do so by concentrating or diluting glomerular filtrate. Consequently, a low urine specific gravity (e.g. 1.008) may not be abnormal, but reflect the kidneys' appropriate response to increased fluid intake. How urine specific gravity is interpreted not only depends on its value but also on the hydration status of the body and the conditions or diseases that alter or interfere with normal kidney function. We recommend that as an alternative to a normal reference range commonly used for serum biochemical values, a more clinically useful designation for urine specific gravity would be 1) maximally concentrated (near 1.060 for dogs and near 1.080 for cats; in order for the kidney to concentrate to this level kidneys have to be in high functioning order), 2) adequately concentrated (≥1.030 for dog and ≥ 1.035 to 1.040 for cats; we use the term adequately to indicate that it is adequately concentrated to prevent the signs of primary kidney failure (e.g. vomiting, anorexia)), or 3) inappropriate concentrated (between 1.007 and 1.030 for dogs and between 1.007 and 1.035 to 1.040 for cats); urine specific gravity is only inappropriate in animals that are dehydrated or azotemic (because in these conditions the kidneys would normally conserve water by forming a more concentrated urine). In animals that are adequately hydrated and not azotemic, urine specific gravity can encompass the entire physiological range (approximately 1.001 to 1.060 in dogs and 1.001 to 1.080 in cats) depending on the body's need to conserve or remove water.

References

- Osborne CA, Stevens JB. Urinalysis: a clinical guide to compassionate patient care. Bayer Corporation, Shawnee Mission Kansas USA, 1999.
- Watson ADJ, Urine specific gravity in practice. Austrailian Veterinary Journal. 1998; 76. 392-398.
- George JW. The usefulness and limitations of hand-held refractometers in veterinary medicine: an historical and technical review. Veterinary Clinical Pathology. 2001;30:201-210.

UROLOGY

Table 1. Interpreting Urine Specific Gravity

Urine specific gravity	Hydration Status	Azotemia	Classification of urine concentration	Interpretation	Associated clinical conditions
1.050-1.060 (D)[1] 1.060-1.080 (C)[1]	Normal	No	Maximal	Very Healthy kidneys	Health
	Dehydrated	No	Maximal	Healthy kidneys	Dehydration from any cause
	Dehydrated	Yes	Maximal	Prerenal Azotemia	Vomiting-common Water restriction-common
>1.030-1.040 (D) >1.035-1.050 (C)	Normal	No	Adequate[2]	Healthy	Health
	Dehydrated	No	Adequate	Renal function is sufficient to maintain homeostasis	Health Nonazotemic kidney disease
	Dehydrated	Yes	Adequate	Prerenal azotemia	Health Nonazotemic kidney disease
<1.030 (D) <1.035-1.040 (C)	Normal	No	Normal	Renal function is sufficient to maintain homeostasis	Health Excessive water consumption Nonazotemic kidney disease
	Dehydrated	No	Inappropriate	Impaired renal function such that water homeostasis is disrupted	Kidney disease Diseases inhibiting generation of a hyperosmotic renal medulla (e.g. hypercortisolemia; table 2). Diseases reducing renal tubular sensitivity to ADH (e.g. UTI, Table 2) Conditions promoting osmotic diuresis (e.g. glucosuria, fluid administration; table 2)
	Dehydrated	Yes	Inappropriate	Kidney failure (CKD)	Kidney failure (CKD)
1.008-1.012	Normal	No	Normal	Healthy	Health Possible early kidney disease
	Hypervolemic	Yes	Fixed	Advanced kidney failure (disease)	Later or end stage kidney failure (disease)
	Dehydrated	No	Inappropriate	Impaired renal function such that water homeostasis is disrupted	Kidney disease Diseases inhibiting generation of a hyperosmotic renal medulla (e.g. Structural kidney disease, hypercortisolemia; table 2). Diseases reducing renal tubular sensitivity to ADH (e.g. kidney failure, UTI, Table 2) Conditions promoting osmotic diuresis (e.g. glucosuria, fluid administration; table 2)
	Dehydrated	yes	Inappropriate	Kidney failure	Kidney failure
<1.007	Normal or hypervolemic	No	Normal	Healthy	Health Polydipsia Excessive fluid administration
	Dehydration	No	Inappropriate	Lack of ADH or insensitivity to ADH	Central diabetes insipidus Nephrogenic diabetes insipidus
	Dehydrated	Yes	Inappropriate	Lack of ADH or insensitivity to ADH	Prerenal azotemia combined with central diabetes insipidus or nephrogenic diabetes insipidus

1. *Administration of iodinated contrast agents may falsely elevate USG*
2. *Adequate implies that USG is adequately (e.g. sufficiently) concentrated such that the primary renal failure is unlikely*

D = dog, C= cat, USG= urine specific gravity, ADH=Antidiuretic hormone, UTI=urinary tract infection