Original Study

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Effects of fluid therapy on total protein and its influence on calculated unmeasured anions in the anesthetized dog

Alexander Valverde, DVM, DVSc, Dip. ACVA; M. Erin Hatcher, DVM and Henry R. Stämpfli, DVM, Dr. Med. Vet., Dip. DACVA, DACVIM

Abstract

Objective – To determine the effects of IV lactated Ringer's solution at a rate of 10 mL/kg/h in anesthetized dogs on total protein (TP) measurement and calculation of unmeasured anions (UAs) using 2 quantitative methods of acid-base status determination, strong ion gap, and modified base deficit.

Design – Prospective clinical study.

Animals – Forty-three dogs, anesthetic health status I or II according to the American Society of Anesthesiologists, undergoing surgery under general anesthesia.

Interventions – Arterial blood analyses for gas tensions, acid-base balance, electrolytes, lactate, hemoglobin (Hb), PCV, and TP were performed under general anesthesia immediately after induction and again after administration of approximately 10 mL/kg of lactated Ringer's solution (given over 1 h). UAs were determined using strong ion gap and modified base deficit.

Measurements and Main Results – Fluid replacement for 1 hour decreased TP, Hb, and PCV by 8%, 7.8%, and 8.6%, respectively. The degree of decrease in TP did not impact the calculation of UAs by quantitative methods when the prefluid administration TP value was used instead of the postfluid TP value in the calculation. Comparison of the two methods showed a low correlation ($r \leq 0.68$) and marked differences in the precision (1.96 SD).

Conclusions: The degree of decrease in TP after 1 hour of fluid replacement at approximately 10 mL/kg does not affect determination of UAs when prefluid TP is used within that time period.

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Introduction

Blood-gas analysis during general anesthesia is commonly performed to assess the acid-base status of the patient. Interpretation can be performed using the traditional approach, based on the evaluation of plasma HCO_3^- and/or base excess that measure disturbances in metabolic acid-base balance and the other factors included in the Henderson-Hasselbalch equation (pH and $PaCO_2$).[1–3] An alternative method for acid-base status interpretation is the physicochemical approach, as described by Peter Stewart (Stewart's method), based on the quantification of independent variables that include $PaCO_2$, total weak acids (plasma proteins), and the strong ion difference (SID) of major plasma electrolytes (Na^+, K^+, Cl^-).[2–7]

Stewart's method is difficult to apply in clinical situations due to the complexity of the multiple equations necessary to quantify the role of the independent variables. Therefore, more simple variations of Stewart's method have been suggested for clinical application, including strong ion gap (SIG) and modified base deficit

From the Department of Large Animal Clinical Sciences, University of Florida, Gainesville, FL 32610 (Valverde, Erin Hatcher), Department of Clinical Studies, Ontario Veterinary College, University of Guelph, Guelph, ON, Canada N1G 2W1 (Stämpfli).

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Alexander Valverde current address: Department of Clinical Studies, Ontario Veterinary College, University of Guelph, Guelph, ON, Canada N1G 2W1.

M. Erin Hatcher current address: All Animal Clinic, Orange Park, FL 32065, USA.

Address correspondence and reprint requests to Dr. Alexander Valverde, Department of Clinical Studies, Ontario Veterinary College, University of Guelph, Guelph, Ontario, Canada N1G 2W1.
Email: valverde@uoguelph.ca

(MBD) methods to estimate the quantity of unmeasured anions (UAs).[2,4,8,9] These methods use some of the independent variables described by Stewart's method, which are readily measured by modern blood-gas and electrolyte analyzers. Total protein (TP) in blood is commonly measured in clinical practice by refractometric methods using the separated blood fraction of microcapillary tubes. Refractometry accuracy may be affected by presence of other nonprotein solids in the plasma fraction such as electrolytes, cholesterol, lipoproteins, urea, and glucose[10]; however, refractometric methods generally correlate well with measurements obtained by the biuret method.[10–12]

Fluid replacement with crystalloids during general anesthesia could potentially cause a decrease in plasma TP due to dilution[13–15] and affect acid-base status. Hypoproteinemia and hyperproteinemia are recognized causes of alkalemia and acidemia, respectively, although the role of plasma proteins is often ignored during clinical acid-base assessment.[6,8,16,17] It is common to use the TP value before fluid therapy, when quantitative methods such as SIG and MBD are used, for additional acid-base determinations over time, therefore neglecting the possible effects of hemodilution on lowering TP and the impact on such calculations.

The purpose of this study was to determine the changes in TP measured by refractometry after 1 hour of fluid replacement and to quantify the consequences on acid-base status in anesthetized dogs by calculating UAs.

Materials and Methods

Animals

Forty-three dogs admitted to the Veterinary Medical Center of the University of Florida for elective surgeries that did not result in significant blood loss (<2% of blood volume) were used. The dogs were a mixed population of males and females (19 males and 24 females), purebreds and mixed breeds, of all ages (6 months to 11 years old) and body weights (8–42 kg) judged to be healthy (American Society of Anesthesiologists classification I or II) based on physical examination and blood work that included at least determination of TP, PCV, and CBC.

Experimental design

All dogs were induced to anesthesia with various techniques that included premedication with an opioid and acepromazine or midazolam, induction with thiopental, propofol, or diazepam/ketamine, and maintenance with sevoflurane or isoflurane in oxygen under spontaneous breathing. Immediately after induction and before surgical fluid replacement administration, an arterial blood sample of at least 1 mL was collected into sodium-heparinized syringes by direct puncture of the dorsal pedal artery or the lingual artery following recommended techniques.[18] Subsequently, lactated Ringer's solution[a] was administered at a rate of approximately 10 mL/kg/h using a catheter (22-, 20- or 18-Ga catheter) placed at the cephalic or saphenous vein and a second arterial sample collected, as previously described, 1 hour later while the dogs were still anesthetized. The fluid rate was delivered using macrodrip or microdrip infusion sets and adjusted manually to deliver the desired number of drops and verified at the end of the 1-hour period by estimating the remaining volume in the fluid bag. All patients were instrumented for blood pressure monitoring using a Doppler,[b] oscillometric method, or direct measurement.[c] Systolic blood pressure and mean blood pressure readings of <90 and 60 mm Hg, respectively, were treated by adjusting the anesthetic depth to a lighter plane. Temperature was monitored using an esophageal or rectal probe[c] and kept between 37° and 38 °C (98.6–100.4 °F) by use of heating devices, including water-heating blanket, forced warm air and blankets. The study was approved by the Institutional Animal Care and Use Committee of the University of Florida.

Analyses

Blood-gas and electrolyte analyses were performed immediately after collection at the dog's body temperature and included the determination of pH, $PaCO_2$, HCO_3^-, base deficit, Na^+, Cl^-, K^+, Ca^{2+}, lactate, and hemoglobin (Hb).[d] The samples were also centrifuged[e] in capillary tubes at 11,500 rpm for 4 minutes to determine PCV and then the plasma fraction placed on a refractometer[f] for TP determination.

From these measurements, SID, anion gap (AG), and UAs were determined for both samples. SID (mEq/L) was calculated from $([Na^+ + K^+] - Cl^-)$.[2,6,7,19] AG (mEq/L) was calculated from $(SID - HCO_3^-)$.[6,7,19]

The measured pH from each sample was compared with a calculated pH based on a computer software program that uses the measured values of $PaCO_2$, Na^+, Cl^-, K^+, Ca^{2+}, and lactate.[g]

UAs were calculated for both samples using 2 methods, MBD and SIG. In addition UAs for the second sample were also calculated using the TP value from the first sample.

MBD

Base deficit/excess measured from arterial blood-gas determinations was corrected using strong ions (Na^+, Cl^-) and TP[2,4,8] and using normal reported canine values for these variables (Table 1).[3,6,16,20,21] Changes in

Table 1: Acid-base and electrolyte data in 43 anesthetized dogs within 5 minutes of induction (sample 1) and 1 hour after induction and fluid replacement with lactated Ringer's solution at 10 mL/kg/h (sample 2)

	Reference values for conscious dogs[3,6,16,21,22]	Sample 1 (mean ± SD)	Sample 2 (mean ± SD)
pH_a	7.381 ± 0.025	7.258 ± 0.066	7.262 ± 0.072
$PaCO_2$ (mm Hg)	40.2 ± 3.4	49.0 ± 10.0	49.0 ± 10.0
HCO^-_3 (mEq/L)	23.1 ± 2.0	20.8 ± 2.3	21.0 ± 2.5
Base deficit (mEq/L)	−2.1 ± 2.3	−5.8 ± 2.3	−5.5 ± 2.8
Na^+ (mEq/L)	147 ± 2.0	144 ± 3.0	143 ± 3.0
K^+ (mEq/L)	4.0 ± 0.3	3.7* ± 0.4	3.9 ± 0.5
Ca^{2+} (mEq/L)	1.3 ± 0.04	1.2 ± 0.1	1.2 ± 0.1
Cl^- (mEq/L)	111 ± 3.0	116 ± 3.5	115 ± 4.0
Lactate (mEq/L)	1.7 ± 0.5	1.6 ± 1.4	1.8 ± 1.4
Total protein (g/L)	61 ± 6.0	62* ± 6.9	57 ± 6.4
Total protein (g/dL)	6.1 ± 0.6	6.2* ± 0.7	5.7 ± 0.6
Hemoglobin (g/dL)	13.6 ± 1.8	11.6* ± 1.9	10.7 ± 1.6
Hemoglobin (g/L)	136 ± 18	116* ± 19	107 ± 16
Packed cell volume (%)	38–48	35* ± 5	32 ± 4
Anion gap (mEq/L)	17.0 ± 2.0	11.5* ± 3.2	10.5 ± 3.3
Strong ion difference (mEq/L)	34–44	32.3 ± 0.5	31.5 ± 0.6
Modified base deficit (mEq/L)	NA	0.34 ± 4.78	0.12 ± 4.19
Strong ion gap (mEq/L)	−8 to 2	−5.8 ± 3.1	−5.6 ± 3.0
Electroneutrality (mEq/L)	NA	−3.4 ± 3.3	−3.7 ± 3.0

*Significantly different from Sample 2. NA, not available.

free water on the Na^+ and Cl^- concentration were calculated from[6,19]:

$$Na^+ \text{ modification (mEq/L)} = 0.25 \times ([Na^+ \text{ measured}] - 147) \quad (A)$$

where 0.25 is the constant in dogs for the change in SID caused by a change in Na^+,[22] and

$$Cl^- \text{ modification (mEq/L)} = 111 - \left([Cl^- \text{ measured}] \times \frac{147}{[Na^+ \text{ measured}]}\right) \quad (B)$$

Changes in TP[6] were calculated from

$$\text{TP modification (mEq/L)} = 0.3\ (61 - [\text{TP measured}]) \quad (C)$$

where 0.3 is the net negative charge constant to convert g/L of TP into mEq/L.

The base deficit due to UAs was calculated from the difference between the base deficit/excess from the blood-gas analysis minus Na^+ modification minus Cl^- modification minus TP modification minus lactate.[2,9] Lactate was not considered an UA because it was determined as part of the blood-gas analysis.

$$UA = \text{base excess/deficit} - (A + B + C + \text{lactate})$$

SIG

A simplified form of SIG[8] was used in order to use the electrolytes and TP used with the MBD method.

$$UA = AG - ([0.25 \times \text{TP measured}] + \text{lactate})$$

where 0.25 is the net negative charge constant to convert g/L of TP into mEq/L.[16]

A rough estimate of electroneutrality was calculated from all measured variables for each sample using $([Na^+ + K^+ + 2\,Ca^{2+}] - [Cl^- + HCO_3^- + \text{lactate} + \text{TP (g/L)} \times 0.175])$.[23]

Statistical analysis

For comparison of the SIG and MBD methods used to determine UAs, a Bland-Altman analysis[24] was used for each of the 3 UAs determinations using a computer program.[h] Bias was defined as the mean value of the differences between MBD and SIG. Precision (limits of agreement) was defined as 1.96 SD of the differences, to include 95% confidence intervals. In addition, regression analyses were used to determine the *r*-value and to examine the linear relationship between SIG and MBD, between PCV and Hb, and between measured pH and calculated pH.

All corresponding individual measurements and calculations from both samples were compared using a paired *t*-test for normally distributed data and with a Wilcoxon signed rank test for nonnormally distributed data. Normal distribution was verified using the Shapiro-Wilk test. Statistical significance was set at $P < 0.05$.

Descriptive statistics were used to calculate the percentage change in TP, PCV, and Hb.

Table 2: Comparison of correction of total protein for the second sample for each method (SIG and MBD) and comparison between quantitative methods SIG and MBD for each of the 3 calculations of UAs using Bland-Altman analyses

	Bias (mEq/L)	Precision (mEq/L)	Correlation coefficient (*r*)	*P* value
SIG (UA2 TP1–UA2 TP2)	−1.3	1.4	0.97	<0.001
MBD (UA2 TP1–UA2 TP2)	1.6	2.7	0.98	<0.001
(SIG–MBD) (UA1)	−6.1	14.3	0.68	<0.001
(SIG–MBD) (UA2 TP2)	−5.7	12.9	0.68	<0.001
(SIG–MBD) (UA2 TP1)	−8.5	12.4	0.66	<0.001

SIG, Strong ion gap method; MBD, Modified base deficit method; UA1, calculated unmeasured anions from sample 1 using TP from same sample; UA2 TP1, calculated unmeasured anions from sample 2 using total protein from sample 1; UA2 TP2, calculated unmeasured anions from sample 2 using total protein from sample 2.

Results

Anesthetic drugs used included an opioid (morphine, hydromorphone, or butorphanol) in all cases; other drugs included acepromazine ($n = 32$), midazolam ($n = 11$), thiopental ($n = 8$), propofol ($n = 17$), diazepam/ketamine ($n = 18$), isoflurane ($n = 28$), and sevoflurane ($n = 15$). Surgeries performed included orthopedic procedures (tibial plateau leveling osteotomy, implant removal; $n = 12$), ophthalmic (cataract removal; $n = 2$), urogenital (spay, neuter, cystotomy; $n = 20$), and soft tissue resection or debridement (mass removal, perineal hernia; $n = 9$).

TP, Hb, and PCV were significantly decreased by 8% ($P < 0.001$), 7.8% ($P < 0.001$), and 8.6% ($P < 0.001$), respectively, after 1 hour of fluid administration at 10 mL/kg. AG was also significantly decreased ($P = 0.01$), whereas K^+ was significantly increased ($P = 0.01$) (Table 1).

Determination of UAs for the second sample using TP values before or after fluid administration did not result in significant differences for any of the methods used ($r = 0.97$ for SIG method and $r = 0.98$ for the MBD method) (Table 2). When the 2 methods were compared for any of the samples, there were significant differences indicated by low correlation coefficients and marked differences in the precision (1.96 SD).

There was a very good correlation between PCV and Hb for both samples ($r = 0.95$ [$P < 0.001$] and $r = 0.93$ [$P < 0.001$] for the first and second sample, respectively; $r = 0.95$ [$P < 0.001$] for both samples combined) (Table 1).

The correlation between measured pH and calculated pH for each sample was $r = 0.60$, $P < 0.001$ (Figure 1). Calculated electroneutrality was < 0 in the majority of the dogs (39 dogs for sample 1 and 40 dogs for sample 2) and > 0 in 4 of the dogs for samples 1 and 3 of the dogs for sample 2 (Figure 2).

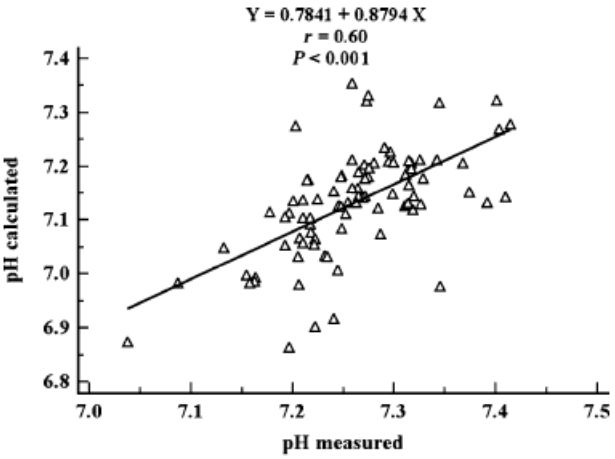

Figure 1: Raw data of the correlation between pH calculated from data measured from the blood gas (electrolytes, total protein, and lactate) and pH measured by the automated system in 86 samples.

Discussion

The relative concentrations of Na^+, K^+, and Cl^-, along with plasma proteins and total carbon dioxide, are the principal determinants of acid-base balance as well as the health status of the patient.[5–8] In a clinical setting, SID can be calculated to determine the amount of strong cations in excess of the strong anions. Strong cations include Na^+ and K^+, while strong anions include Cl^-. Therefore, Na^+ and Cl^- are the major determinants of SID due to their plasma concentrations.[19] The SID measured in the present study was slightly lower (31.4 mEq/L for both samples) than reported values (34–44 mEq/L).[3] A decreased SID is usually the result of an increased Cl^- or UAs (lactate, ketoacids), or a decrease in Na^+, and reflects a metabolic acidosis.[6,25] Na^+ was slightly lower and Cl^- higher than normal reported values, which would explain the decreased SID. In addition, pH and HCO_3^- were decreased and base deficit was increased in dogs in the present study. Metabolic acidosis is a frequent finding in dogs, regardless of their health status, manifested by a lower than normal pH and HCO_3^- and an increased base deficit.[21] In fact, in the present study, values for pH and HCO_3^- were lower and values for base deficit higher, in all patients, than reported normal values, even at the high percentile (75th) for both samples. Respiratory depression as a result of general anesthesia contributed to the higher CO_2, which dissolves in water to form carbonic acid to finally dissociate to

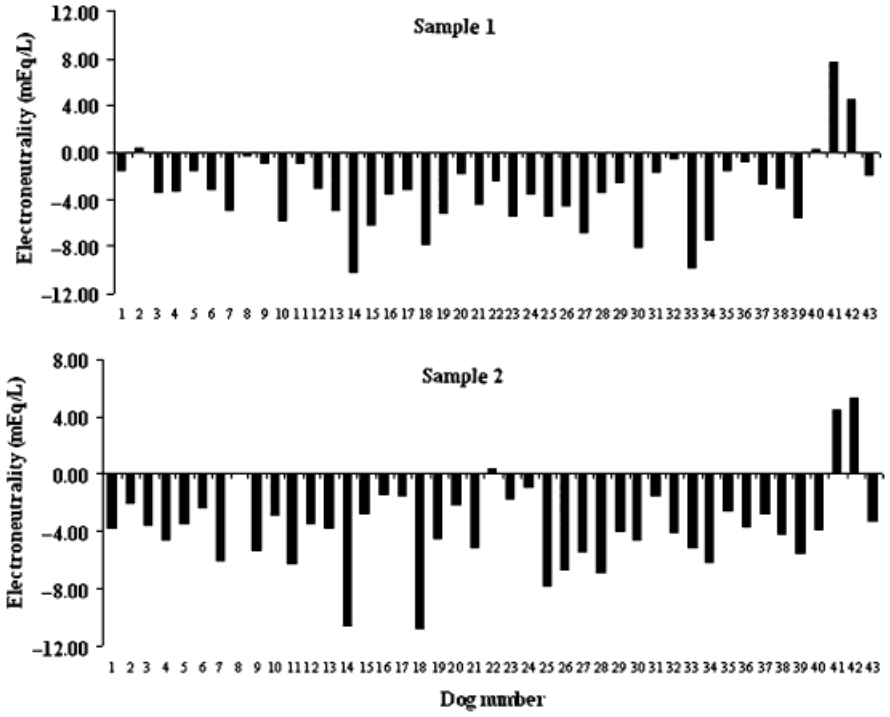

Figure 2: Electroneutrality of samples 1 and 2 calculated using the values for ($[Na^+ + K^+ + 2\ Ca^{2+}] - [Cl^- + HCO_3^- + \text{lactate} + \text{TP (g/L)} \times 0.175]$).

H^+ and HCO_3^-.[2] As a consequence of this reaction, a lower pH from respiratory acidosis was expected but not lower HCO_3^- concentrations.

In the present study, the AG for each sample (11.5 and 10.5 mEq/L for the first and second sample, respectively) was lower than values reported as normal in the literature (17 mEq/L).[6] AG is usually elevated in cases of metabolic acidosis, which is in contrast to our findings. Hypoproteinemia, and more specifically hypoalbuminemia, can mask an increased concentration of gap anions by lowering the value of the AG.[17] However, TP values for the first sample were within normal reported values and not affected by fluid therapy; therefore, other causes may have influenced AG. The majority of the normal AG is attributable to the negative charge on plasma proteins (mainly albumin).[16] The remainder of the AG corresponds to the SIG and is represented by the difference between the concentrations of the unmeasured cations (Ca^{2+} and Mg^{2+}) and the UAs (phosphate, sulfate, and lactate). Changes in unmeasured cation concentrations must be large to change the AG and such changes are incompatible with life.

Plasma proteins are made up of amino acids that act as weak acids and represent a buffer system in the plasma in most species. Albumin is considered the major determinant of total weak-acid concentration.[18] If plasma proteins are increased, there are more of these weak amino acids that can generate or donate protons and the $[H^+]$ will increase.[2,6,16,17,19] Conversely, if there is a decrease in plasma proteins, such as after fluid administration, the $[H^+]$ will decrease and cause alterations in UAs; therefore, the true values for such UAs would be unknown.

In the present study, the administration of approximately 10 mL/kg of lactated Ringer's solution for 1 hour decreased TP values between the first and second sample by 5 g/L and AG by 1.0 mEq/L but did not impact the amount of UAs measured with either method (SIG or MBD). Hypoproteinemic (hypoalbuminemic) patients have a subnormal AG[17,19]; the decrease in AG of 0.20 mEq/g detected in this study, caused by hemodilution, is similar to other previously reported values (0.37[17] and 0.25 mEq/g).[16] The decrease in TP represents a decrease of only 1.25 mEq/L (5 g/L × 0.25 mEq/g) in the negative charge exerted by these weak acids, which had minimal impact on pH and HCO_3^- concentrations.

SIG may be more specific in detecting the presence of unmeasured strong ions (such as lactate) in plasma than AG because it quantifies the effects of anions such as albumin, globulins, and phosphate in its estimations.[12] A decrease in SIG or MBD is a more common clinical situation than an increase; it reflects a decrease in unmeasured strong cations or, more likely, an increase in unmeasured strong anions. In the presence of

normochloremia or hypochloremia, a decrease in SIG or MBD indicates the presence of unmeasured strong anions, whereas an increase indicates the presence of unmeasured cations, a rare event.[16] We did not observe a change in UAs.

The agreement in calculated UAs for the second sample using the undiluted (prefluid) and diluted (postfluid) TP value in the calculations for either method (SIG or MBD) was very good and within acceptable limits of bias (± 1.6 mEq/L) and limits of agreement (± 2.7 mEq/L). Therefore, prefluid administration values for TP can be used to calculate UAs in the first hour of fluid therapy, without affecting the interpretation under circumstances that mimic our study (ie, minimum blood loss and fluid replacement rate at ≤ 10 mL/kg/h). Blood loss of $<2\%$ blood volume was confirmed by measuring the amount of blood in the suction bottle and assigning a volume of 5 mL for each 4 in. $\times$ 4 in. gauze tainted with blood. The effects of significant blood loss or higher fluid rates on TP and calculated UAs by these methods remains to be determined.

The comparison between the SIG and MBD methods, for any of the 3 calculated UAs, resulted in low agreement and unacceptable limits of bias (> -5.7 mEq/L) and precision (>12.4 mEq/L). Both methods have not been compared previously and, although both determine UAs, the calculations that lead to UAs are different in the constants for protein negative charge (0.3 in the MBD method and 0.25 in the SIG method), the electrolytes used (MBD does not include K^+) and the use of HCO_3^- with SIG but not MBD, which might explain part of the differences observed. Our results indicate that their use is not interchangeable and therefore trends for UAs should be calculated using only 1 of the 2 methods.

The law of electroneutrality for watery biologic solutions states that the sum of the cations must equal the sum of anions in aqueous solutions at all times[6]; however, in the present study electroneutrality was not demonstrated. The majority of the values trended towards a negative value in electroneutrality, indicating the presence of unmeasured strong cations and an unexpected physiological situation. Therefore, a measurement error is possible due to lack of accuracy from automated measuring systems. The calculated pH value obtained from the electrolyte and TP determinations was not highly correlated to pH values measured by the automated system, which also demonstrates the lack of accuracy of such equipment when electroneutrality is not considered. The application of the law of electroneutrality to automated systems has been recommended as an adjunct quality control of measuring accuracy of such systems.[26]

TP is not affected by preanesthetic or induction drugs, including acepromazine, medetomidine, butorphanol, thiopental, propofol, ketamine, and diazepam[27]; however, it decreases significantly during anesthesia as a result of a dilutional effect from fluid therapy. One limitation of our study is the lack of a control group in which fluids were administered to awake dogs to assess the effects on TP, PCV, and electrolytes; however, our goal was to determine such effects in anesthetized patients. An alternative was also to have a control group with anesthetized dogs receiving no fluids to assess this regime on TP, PCV, and electrolytes. However, studies with halothane-anesthetized dogs receiving fluid replacement at 10–20 mL/kg/h demonstrated that TP decreased by 10–15%[13,14,27] and did not change from baseline without fluid replacement after approximately 1 hour,[13,15] whereas PCV changed minimally from the time of induction to approximately 60 minutes after fluid replacement at 0–20 mL/kg/h.[13–15,27] The effects of surgery on TP are less well characterized; however, TP did not change significantly in cats undergoing splenectomy[28] and in horses undergoing surgery under thiopental and chloroform anesthesia.[29] Electrolytes (Na^+, K^+, Mg^{2+}, and Ca^{2+}) remained stable in dogs anesthetized for periods of 2–21 days,[30] whereas in horses anesthetized for 40 minutes, Na^+ and Cl^-, but not K^+, concentrations decreased significantly; however, the observed changes were not clinically relevant.[29] In our study the greatest change observed for any of those 3 electrolytes was 1 mEq/L. A recent study detected statistically significant decreases in arterial and venous ionized Ca^{2+} and increases in ionized or total Mg^{2+} in samples collected after various anesthetic protocols (opioids, acepromazine, benzodiazepines, xylazine, propofol, lidocaine, thiopental, ketamine, and isoflurane), and surgeries of <3.5 hours in healthy dogs and cats when compared with awake values.[31] These changes were not considered clinically relevant because values were within normal reference range.[31] We did not use either cation for the calculations of UAs and Ca^{+2} did not change in our study.

In the present study, TP decreased by 8% and had minimal effects on UAs; however, it is possible that fluid replacement for a longer period or at a higher rate may cause a further decrease in TP that affects acid-base balance and UAs. In addition, if the health status of the animal is critical, protein content may be already affected by disease, blood loss during surgery, and other factors that impact TP significantly, making use of current TP values important to avoid miscalculations of UAs.

The refractometer used in this study accounts for the conversion factor for solutes in blood to protein so that

a high correlation exists between total solids and TP.[10] Nonprotein substances measured in our samples were relatively constant, including electrolytes, glucose (not reported), and therefore did not interfere with the accuracy of this method.

The correlation coefficient between PCV and Hb was very good ($r = 0.95$). Anesthetic drugs, such as acepromazine are implicated in marked drops in PCV, whereas others, such as ketamine and diazepam, do not affect it.[27] In addition, inhalant anesthetics can also decrease PCV due to their vasodilatory effects.[32] Most of the significant changes in PCV from baseline were reported to occur in the preoperative period, after premedication with acepromazine, due to the vasodilatory effects and subsequent sequestration by multiple organs.[27] Subsequent changes in PCV after induction are less significant. We measured PCV immediately after induction and showed an 8.6% reduction after 1 hour of fluid replacement.

The decrease in PCV of 8.6% is the result of expansion of the blood volume by 9.4% ($\{100/[100-8.6] \times 100\} - 100$). The mean PCV in the first sample was 35%, which corresponds to a plasma volume of 65%. The expansion in blood volume of 9.4% should result in a 14.5% increase in plasma volume ($\{[65+9.4] \times 100/65\} - 100$); however, the decrease in TP of 8% was significantly lower in this study than the corresponding dilution of the plasma volume. This is in contrast to another study in human volunteers[33] receiving approximately 27 mL/kg of saline or dextrose for 1 hour in which a greater proportional change in protein concentration occurred compared with PCV and was attributed to the increase net loss of albumin into the interstitium because of dilution of the plasma colloid oncotic pressure by the fluids.[33,34] Possible causes for this difference include the use of anesthetic drugs and their cardiovascular effects, surgical stimulation and a lower fluid rate used in our study that resulted in different dynamics of fluid movement between the interstitium and intravascular space.

In conclusion, this study demonstrated that in anesthetized dogs the decrease in TP as a result of fluid replacement at approximately 10 mL/kg for 1 hour does not affect the determination of UAs during the first hour if the prefluid administration TP value is used.

Footnotes

[a] LRS, Baxter Healthcare Corporation, Deerfield, IL.
[b] Ultrasonic Doppler flow detector, Parks Medical Electronics Inc, Aloha, OR.
[c] Datascope passport, Datascope Corp, Mahwah, NJ.
[d] ABL 700 Series, Radiometer Medical A/S, Copenhagen, Denmark.
[e] IEC MB Centrifuge, International Equipment Company, Needham Heights, MA.
[f] Refractometer, Jorgensen Laboratories Inc, Loveland, CO.
[g] Scientific solutions calculator software using the Stewart approach equations and Excel Microsoft 5.0. Copyright Dr. H. Stämpfli, University of Guelph, Canada.
[h] MedCalc Software, version 9.3.2.0, Mariakerke, Belgium.

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