Advances in Fluid, Electrolyte, and Acid-Base Disorders

CONTENTS

Preface xvii
Helio Autran de Morais and Stephen P. DiBartola

Quick Reference

Hypoxemia: A Quick Reference 423
Jonathan F. Bach

The article describes the calculation of the alveolar-arterial gas gradient and its clinical application in determining the cause of hypoxemia. It also outlines the analysis of arterial blood gases and the clinical approach toward diagnosis and treatment of respiratory disease.

Respiratory Alkalosis: A Quick Reference 427
Rebecca A. Johnson

This article serves as a quick reference for respiratory alkalosis. Guidelines for analysis and causes, signs, and a stepwise approach are presented.

Respiratory Acidosis: A Quick Reference 431
Rebecca A. Johnson

This article serves as a quick reference for respiratory acidosis. Guidelines for analysis and causes, signs, and a stepwise approach are presented.

Metabolic Alkalosis: A Quick Reference 435
Daniel Foy and Helio Autran de Morais

This article serves as a quick reference for metabolic alkalosis. Guidelines for analysis and causes, signs, and a stepwise approach are presented.

Metabolic Acidosis: A Quick Reference 439
Helio Autran de Morais

This article serves as a quick reference for metabolic acidosis. Guidelines for analysis and causes, signs, and a stepwise approach are presented.
Anion Gap and Strong Ion Gap: A Quick Reference  
Jennifer Kaae and Helio Autran de Morais

This article serves as a quick reference for the anion gap and strong ion gap. Guidelines for analysis and interpretation of changes are presented.

Hypercalcemia: A Quick Reference  
Patricia A. Schenck and Dennis J. Chew

This article serves as a quick reference for hypercalcemia. Guidelines for causes, clinical signs, analysis, and diagnosis are presented in a stepwise approach.

Hypocalcemia: A Quick Reference  
Patricia A. Schenck and Dennis J. Chew

This article serves as a quick reference for hypocalcemia. Guidelines for causes, clinical signs, and diagnosis are presented in a stepwise approach.

Chloride: A Quick Reference  
Alexander W. Biondo and Helio Autran de Morais

This article serves as a quick reference for the analysis of chloride abnormalities. Guidelines for causes, signs, and stepwise approaches for corrected hypochloremia and hyperchloremia are presented.

Magnesium: A Quick Reference  
Shane W. Bateman

This article serves as a quick reference for the distribution, handling, and supplementation of magnesium. It also lists the manifestations and causes of magnesium deficit and provides criteria for the diagnosis of a magnesium deficit.

Phosphorus: A Quick Reference  
Julia A. Bates

This article gives a brief overview of phosphorus. The author addresses the main functions of phosphorus in the body, the causes and manifestations of hypophosphatemia and hyperphosphatemia, and suggests further readings.

Hyperkalemia: A Quick Reference  
Marcia Mery Kogika and Helio Autran de Morais

This article serves as a quick reference for hyperkalemia. Guidelines for analysis and causes, signs, and a stepwise approach are presented.
Hypokalemia: A Quick Reference 481
Marcia Mery Kogika and Helio Autran de Morais

This article serves as a quick reference for hypokalemia. Guidelines for
analysis and causes, signs, and a stepwise approach are presented.

Hypernatremia: A Quick Reference 485
Helio Autran de Morais and Stephen P. DiBartola

This article serves as a quick reference for hypernatremia. Guidelines
for analysis and causes, signs, and a stepwise approach are presented.

Hyponatremia: A Quick Reference 491
Helio Autran de Morais and Stephen P. DiBartola

This article serves as a quick reference for hyponatremia. Guidelines for
analysis and causes, signs, and a stepwise approach are presented.

Electrolyte and Acid-Base Disorders

Calcium: Total or Ionized? 497
Patricia A. Schenck and Dennis J. Chew

Measurement of serum total calcium (tCa) has been relied on for as-
sessment of calcium status, despite the fact that it is the ionized calci-
um (iCa) fraction that has biologic activity. Serum tCa does not
accurately predict iCa status in many clinical conditions. For accurate
assessment of iCa status, iCa should be directly measured. Anaerobic
measurement of serum iCa under controlled conditions provides the
most reliable assessment of calcium status; aerobic measurement of
iCa with species-specific pH correction is highly correlated with anaer-
obic measurements.

Urinary Electrolytes, Solutes, and Osmolality 503
Jennifer E. Waldrop

Urine chemical analysis can extend “beyond the dipstick” with an un-
derstanding of renal physiology and expected changes in electrolyte
and solute handling. Urine electrolytes, such as sodium and chloride,
can be helpful in discerning prerenal azotemia from acute renal tubu-
lar damage, which occur secondary to nephrotoxins or ischemia. Urine
osmolality also is essential in determining appropriate antidiure-
retic hormone action and renal water handling. Urine solutes, such
as albumin and brush border enzymes, may be more sensitive than
plasma markers for early renal dysfunction. This article reviews
these topics and the use of “extended” urine indices in veterinary
medicine.
Therapeutic Approach to Electrolyte Emergencies

Hypokalemia, hyperkalemia, hyponatremia, hypernatremia, hypocalcemia, and hypercalcemia are commonly seen in emergency medicine. Severe abnormalities in any of these electrolytes can cause potentially life-threatening consequences to the patient. It is essential that the clinician understand and correct (if possible) the underlying cause of each disorder and recognize the importance of the rates of correction, especially with serum sodium disorders. The recommended doses in this article might have to be adjusted to the individual patient, and these modifications must be adjusted again to the pathophysiology of the primary underlying disorder.

Therapeutic Approach to Chronic Electrolyte Disorders

Chronic disorders of sodium and potassium occur and occasionally need symptomatic therapy. Hypernatremia primarily indicates loss of free water, whereas hyponatremia may be attributable to various problems. It is important not to correct major aberrations of serum sodium concentrations too quickly lest the therapy be more detrimental than the electrolyte abnormality. In distinction, hypokalemia and hyperkalemia may be corrected quickly. Hypomagnesemia is relatively common, but its clinical significance is still being determined.

Making Sense of Blood Gas Results

Recent technologic advances have allowed the production and marketing of cage-side blood gas analyzers to private practitioners. The widespread use of cage-side portable blood gas analyzers in veterinary practices has increased the need to develop the basic skills of blood gas analysis as part of a tool kit for practicing veterinarians. Rapid expansion of emergency and critical care medicine as a specialty and increased numbers of veterinary emergency and veterinary specialty practices have occurred concurrently with the availability of blood gas analyzers that are affordable for private practitioners. As a result, evaluation of blood gas results is no longer an activity confined to academic institutions and has become a daily part of many practicing veterinarians’ activities.

Metabolic Acid-Base Disorders in the Critical Care Unit

The recognition and management of acid-base disorders is a commonplace activity in the critical care unit, and the role of weak and strong acids in the genesis of metabolic acid-base disorders is reviewed. The
clinical approach to patients with metabolic alkalosis and metabolic acidosis is discussed in this article.

**Fluid Therapy**

**Fluid Therapy: Options and Rational Administration**

Steven Mensack

Fluid administration is a primary component of therapy in many small animal patients. Several different classes of fluid may be given, and there are multiple options within each class. The type, route, volume, and rate of fluid administered should be tailored to the patient’s signalment, disease or injury state, and response to the administration of fluids. Monitoring vital parameters and bedside monitoring of laboratory variables allow assessment of fluid therapy success or failure. Successful fluid administration also requires that parenteral fluid therapy ultimately be discontinued with minimal adverse effects for the patient.

**Colloids: Current Recommendations**

Daniel L. Chan

Colloids are increasingly becoming considered indispensable in the management of critically ill patients. Typical indications for colloid administration include patients with tissue edema, hypovolemia, and low oncotic pressure. Current guidelines for the use of colloids in veterinary patients balance the purported benefits of colloid fluid administration with the potential risks, such as volume overload and coagulation disturbances. This article focuses primarily on hydroxyethyl starches, because they are the most commonly used colloid in veterinary practice, and because recent advances in colloid therapy have been achieved with this colloid. Newer colloids have been modified to limit effects on the coagulation system, and they may be used to modulate the inflammatory response, which could prove to be particularly useful in the management of critically ill patients. A better understanding of how different fluids influence the host response may enable us to explore new applications of fluid replacement therapy beyond simply replenishing volume deficits.

**The Therapeutic Use of 25% Human Serum Albumin in Critically Ill Dogs and Cats**

Karol A. Mathews

Twenty-five percent human serum albumin (HSA) is a foreign protein and can potentially cause immune-mediated reactions. For this reason, the author only recommends 25% HSA use after risk analysis shows that the benefits outweigh the potential risks of adverse events. If it is apparent that a critically ill animal may succumb to its illness because of the problems associated with severe hypoalbuminemia, the benefit outweighs the risk. The veterinarian must inform the owner of potential
delayed immune-mediated reactions, describe these lesions, and follow
the case weekly to ensure that no reaction has occurred. Although there
are many positive attributes to the administration of 25% HSA, there
seems to be specific situations in which 25% HSA may be indicated
and others in which it may not be indicated.

**Complications of Fluid Therapy**

Elisa M. Mazzaferro

The intravenous administration of fluids is one of the most important
aspects of patient care in hospitalized animals. Intravenous fluids are ad-
ministered to replace or prevent dehydration, treat hypovolemic shock
and intravascular volume depletion, correct acid-base and electrolyte
abnormalities, and maintain vascular access for administration of drugs,
blood product components, and parenteral nutrition. Intravenous cath-
eterization also can provide a means of blood sample collection, thus
avoiding frequent and uncomfortable venipunctures in critically ill ani-
mals. Although the benefits of intravenous catheterization and fluid ad-
ministration are numerous, inherent risks are associated with the
procedures, and care must be taken to avoid potential complications.

**Pediatric Fluid Therapy**

Douglass K. Macintire

Many conditions of pediatric patients require fluid therapy. Depending
on the veterinarian’s assessment of hydration and perfusion status, flu-
ids can be administered orally, subcutaneously, intraperitoneally, intra-
venously, or by the intraosseous route. Pediatric patients are prone to
hypothermia, hypovolemia, hypoglycemia, and hypokalemia, which
must be addressed during fluid therapy in pediatric patients. Typical pa-
rameters used to assess hydration status in adult animals do not always
apply to pediatric patients. Veterinarians should be aware of differences
between pediatric patients and adult animals in terms of physical assess-
ment, common presentations, and fluid requirements for resuscitation
and maintenance needs.

**Assessment and Treatment of Hypovolemic States**

Garret E. Pachtinger and Kenneth Drobatz

Hypovolemia and hypoperfusion are common life-threatening prob-
lems in animals presented to the emergency veterinarian. Assessment
of physical findings and rapid recognition and treatment of abnormal
tissue perfusion are crucial in optimizing outcome. The clinician should
be familiar with the disease being treated and the types of fluids that are
available. Development of a fluid therapy plan to correct life-threatening
abnormalities and patient monitoring during treatment play an impor-
tant role in patient outcome.
Fluid Resuscitation and the Trauma Patient 645
Elke Rudloff and Rebecca Kirby

Traumatic shock can result from one or more of the following: hypovolemia, increased capillary permeability and vasodilatation, impaired myocardial contractility or dysfunction, blood loss, and cardiovascular obstruction. Animals with traumatic injuries are less tolerant of sudden increases in hydrostatic pressure, which can exacerbate fluid leakage into damaged tissues and disrupt blood clots. Pain amplifies the shock response, and analgesic therapy is always recommended in the trauma patient. Therapy must be individualized and monitored closely.

Fluid Therapy in Vomiting and Diarrhea 653
Andrew J. Brown and Cynthia M. Otto

Fluid therapy in the patient with vomiting and diarrhea is essential to correct hypovolemia, dehydration, acid-base imbalance, and serum electrolyte abnormalities. Prediction of acid-base or electrolyte disturbances is difficult; therefore, point of care testing is beneficial to optimize therapy. This article focuses on the pathophysiology and treatment of hypovolemia, dehydration, electrolyte disturbances, and acid-base derangements resulting from and associated with vomiting and diarrhea.

Managing Fluid and Electrolyte Disorders in Renal Failure 677
Cathy Langston

Because of the role of the kidneys in maintaining homeostasis in the body, kidney failure leads to derangements of fluid, electrolyte, and acid-base balance. The most effective therapy of a uremic crisis is careful management of fluid balance, which involves thoughtful assessment of hydration, a fluid treatment plan personalized for the specific patient, repeated and frequent reassessment of fluid and electrolyte balance, and appropriate changes in the treatment plan in response to the rapidly changing clinical situation of the patient that has renal failure. Disorders of sodium, chloride, potassium, calcium, and phosphorus are commonly encountered in renal failure and may be life threatening. Treatment of metabolic acidosis and nutritional support are frequently needed.

Fluid and Electrolyte Therapy in Endocrine Disorders: Diabetes Mellitus and Hypoadrenocorticism 699
Søren R. Boysen

Diabetic ketoacidosis, hyperglycemic hyperosmolar syndrome, and acute adrenal crisis are life-threatening endocrine emergencies that have marked effects on fluid, electrolyte, and acid-base homeostasis.
Rapid identification of these disorders and aggressive therapy to correct fluid, electrolyte, and acid-base imbalances are crucial to a successful outcome for the patient. An understanding of the pathophysiology behind the development of these endocrine disorders helps to guide therapy and improves the clinical outcome.

**Fluid Therapy in Patients with Pulmonary Disease** 719
Sophie Adamantos and Dez Hughes

Fluid therapy in patients with pulmonary disease is challenging. Although a single set of rules cannot be applied to every patient, the following guidelines can be used when managing patients with pulmonary disease. Euvolemic patients with adequate tissue perfusion should be given sufficient isotonic fluid to balance insensible losses. If severe pulmonary compromise is present, cessation of all fluid therapy may be considered if the patient is able to match its losses by voluntary intake. In hypovolemic or hypotensive patients, small boluses of isotonic crystalloids or colloids should be given to restore perfusion, avoiding rates of more than 30 mL/kg an hour for isotonic crystalloids. If perfusion is not restored by adequate volume resuscitation, vasopressors or positive inotropes should be administered to prevent fluid overload and deterioration in pulmonary function.

**Maintaining Fluid and Electrolyte Balance in Heart Failure** 727
Teresa C. DeFrancesco

Advanced heart failure and its treatment are often associated with a variety of hemodynamic, fluid, and electrolyte derangements. This article gives the practitioner an overview of the pathophysiology of common fluid and electrolyte alterations present in animals with heart failure, highlighting specific clinical correlates. Additionally, specific therapeutic interventions are discussed to manage these fluid and electrolyte abnormalities.

**Index** 747