A.S.P.E.N. Fluids, Electrolytes, and Acid–Base Disorders Handbook

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AMERICAN SOCIETY FOR PARENTERAL AND ENTERAL NUTRITION

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The American Society for Parenteral and Enteral Nutrition (A.S.P.E.N.) is a scientific society whose members are health care professionals; physicians, dietitians, nurses, pharmacists, other allied health professionals, and researchers; that envisions an environment in which every patient receives safe, efficacious, and high quality patient care.

A.S.P.E.N.'s mission is to improve patient care by advancing the science and practice of clinical nutrition and metabolism.

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Print edition: ISBN-13: 978-1-889622-17-0
eBook edition: ISBN-13: 978-1-889622-18-7

Printed in the United States of America.

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Foreword

I am delighted to write the foreword for *The A.S.P.E.N. Fluids, Electrolytes, and Acid–Base Disorders Handbook*. The management of fluids, electrolytes, and acid–base problems is of vital importance. However, the task of managing these issues is often left to many of the more inexperienced members of a medical team. Without thorough training, patients may be at risk for a number of complications. Maintaining a patient's hydration and electrolyte balance is complex and requires an in-depth foundation. Further, managing adults or children who have developed fluid and/or electrolyte disorders can be some of the most challenging aspects of clinical medicine. Such disorders may lead to significant hemodynamic, cardiovascular, respiratory, and neurologic complications, and if not appropriately corrected may lead to death.

Under the editorial guidance of Todd Canada, Sharla Tajchman, Anne Tucker, and Joe Ybarra, this handbook will serve as a wonderful compendium for healthcare professionals who manage the nutrition care of their patients.

The handbook will also provide an excellent reference for routine medical care beyond that centered on nutrition. The handbook is nicely laid out in a sequential order from normal physiologic needs of the patient to defined approaches to disorders in hydration, electrolytes, and acid–base disturbances. The handbook offers stepwise approaches to correct the most important of such disorders, and has separate sections on common clinical scenarios (Chapter 5) and the medical approach to their care. Of key importance is a strong chapter on pediatric considerations (Chapter 6). Each chapter is replete with critical tables and formulas to guide the reader and provide them with a practical approach to patient care.

Key experts in each area have contributed to the six core chapters presented herein. This handbook serves as the perfect pocket companion to other A.S.P.E.N. resources, including *The A.S.P.E.N. Adult Nutrition Support Core Curriculum, 2nd Edition*, *The A.S.P.E.N. Pediatric Nutrition Support Core Curriculum, 2nd Edition*, and A.S.P.E.N's evidence-based clinical guidelines and standards documents.

A.S.P.E.N. believes that the reader will find the easy-to-read format and comprehensive tables and figures to be an excellent guide for bedside clinical use.

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Preface

Appropriate treatment of fluid and electrolyte disorders is imperative in clinical practice to provide quality patient care and ensure positive outcomes. Clinicians and trainees encounter situations daily that require the ability to recognize such disorders, determine their etiology, and provide management recommendations regardless of clinical practice environment. The first edition of *The A.S.P.E.N. Fluids, Electrolytes, and Acid–Base Disorders Handbook* was designed by the editorial team to be a comprehensive source of information on fluids, electrolytes, and acid–base disorders and how each relates to patient care, including appropriate identification and treatment strategies. The handbook offers something for everyone, from the novice to the advanced practitioner irrespective of healthcare background. Experts in the field of fluids, electrolytes, and acid–base disorders were sought to provide the most up-to-date, evidenced-based recommendations. This handbook serves as the perfect pocket companion to the A.S.P.E.N. Adult and Pediatric Core Curriculums, evidence-based guidelines, and standards documents. Its easy-to-read format consisting of tables, figures, bullet point statements, and step-by-step guides make it ideal for bedside use. We hope that this handbook quickly becomes your go-to pocket guide for management of fluids, electrolytes, and acid–base disorders.

The A.S.P.E.N. Fluids, Electrolytes, and Acid–Base Disorders Handbook is organized into six chapters. Chapter 1 lays the foundation for the reader by providing an overview of water regulation and electrolyte balance. Chapters 2 through 4 provide detailed overviews of disorders related to fluids, individual electrolytes, and acid–base homeostasis. Clinical scenarios presented in chapters 1 through 4 allow users to better grasp concepts and further develop clinical skills. Chapter 5 focuses on common clinical situations in which in-depth understanding of fluids, electrolytes, and acid–base balance is required. While the handbook primarily focuses on adult patients, chapter 6 provides insight into pediatric considerations related to fluids, electrolytes, and acid–base homeostasis and its management. To ensure completeness, nutrition support principles and strategies have been incorporated where appropriate.

In closing, we would like to acknowledge that this publication would not have been possible without the countless hours of dedication from our contributors and support from the A.S.P.E.N. Board of Directors and publications staff. We would like to specifically thank Jennifer Kuhn, A.S.P.E.N. director of publications, for her patience and dedication in bringing this publication to print. Her attention to detail and insights into medical publishing will certainly add to the future success of this handbook. It definitely takes a village to bring a book to print.

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The A.S.P.E.N. Fluids, Electrolytes, and Acid–Base Disorders Handbook Editors

CHAPTER 1

Regulation of Water and Electrolyte Balance

Composition of Body Fluids[1]

1. Water
    - Water is the major constituent of the human body accounting for 50% and 60% of lean body weight (LBW) in females and males, respectively (Figure 1-1).
    - Water is associated with lean body mass. Muscle contains approximately 75% water, while adipose tissue only contains 10% water. Factors such as percentage of body fat, age, and sex affect the percentage of total body water (TBW) (Table 1-1).

      TBW (women) = LBW × 0.5

      TBW (men) = LBW × 0.6
    - In obese patients, lean body weight should be used to determine TBW.

      LBW (women) = 1.07 × weight (kg) – 148 × [weight (kg)/height (cm)]^2

CHAPTER 2

Fluid Disorders

Fluid Balance[1]

As introduced in chapter 1, the adult body maintains fluid balance by balancing fluid gains (input) with fluid losses (output) through regulation by 3 main systems:

1. Gastrointestinal (GI) tract
    - The GI tract processes nearly 10 L of fluid each day, almost all of which is reabsorbed by various parts of the normal GI tract.
    - Fluid and electrolyte concentrations of body fluids vary depending on the location along the GI tract (see Table 1-4 in chapter 1).
    - Approximately 100–200 mL of fluid is lost in feces.
2. Kidneys
    - Sodium and water are filtered and reabsorbed through the kidney to maintain homeostasis.
    - The kidneys respond to changes in blood volume by

CHAPTER 3

Electrolyte Disorders

Electrolyte disorders are a common occurrence in clinical practice and are seen in all practice settings from outpatient clinics to the intensive care unit (ICU). An understanding of electrolyte disorders is vital for all clinicians regardless of practice setting. This chapter will discuss the appropriate diagnosis and management of electrolyte disorders related to sodium, potassium, magnesium, calcium, and phosphorus.

Sodium

Overview

Sodium disorders are the most common electrolyte disturbances encountered in clinical practice. Though many cases are mild and asymptomatic, understanding the etiologies, treatments, and management strategies of sodium disorders is clinically important because the disorders and treatments are associated with significant morbidity and mortality if not recognized early and managed appropriately.

1. Homeostasis and physiological function
    - The normal sodium range is 135–145 mEq/L (1 mEq/L = 1 mmol/L).
    - Sodium is the most abundant extracellular cation and acts as a functionally impermeable solute (ie, it does not move passively across membranes).
    - Sodium is the major osmotically active substance in the extracellular fluid (ECF) and maintains the concentration, volume, and osmolality of the ECF compartment.
    - The conduction of action potential in nerves and muscle tissue is dependent on sodium concentration.
2. Dietary intake[1]
    - One gram of sodium chloride is equal to 17 mEq of sodium and 17 mEq of chloride.
    - Adequate sodium intake for adults is 20–26 mEq (1200–1500 mg) per day depending on age and co-morbidities.
    - The typical Western diet contains 100–250 mEq (6–15 g) of sodium per day.
3. Excretion
    - Sodium intake and urinary sodium excretion are balanced in healthy patients, with excess sodium excreted in the urine. The range for urine sodium excretion varies widely and is dependent on diet. Typically, the average patient will excrete 40–200 mEq of sodium per day in the urine.
    - Extrarenal sodium losses via gastrointestinal (GI) fluids and sweat are outlined in chapter 1.
    - The kidneys can compensate for inadequate sodium intake by reabsorbing sodium and minimizing urinary sodium excretion to < 1%.

CHAPTER 4

Acid–Base Homeostasis and Disorders

Identification and management of acid–base disorders play a large role in providing safe and effective patient care. Understanding acid–base homeostasis is a vital step within this process. This chapter begins by providing an overview of acid–base physiology and presenting the clinician with a stepwise process that can be utilized to evaluate arterial or venous blood gases and identify specific acid–base disorders. Once diagnostic strategies are covered, emphasis and review of the individual acid–base disorders will be completed.

Overview

1. Acid–Base Physiology[1]

For normal cell function, consistent acid–base balance via metabolic and respiratory processes must be maintained. Acid–base homeostasis is regulated by the lungs, kidneys, and endogenous chemical buffer systems. The inability of these systems to balance acids and bases is the basic concept of acid–base disorders. Acids are defined as substances that can donate hydrogen ions (H^+) and bases are substances that can accept or combine with H^+.

a. pH: the concentration of H^+ in solution

- pH is measured on a logarithmic scale ranging from 1 to 14.
- A pH of 7 is considered neutral, while values < 7 are acidic and values > 7 are alkalotic.
- The normal physiologic pH range is 7.35–7.45. The body attempts to tightly maintain pH at 7.40.

b. Alterations in pH

- Acidemia: pH < 7.35
- Acidosis: a process associated with an increase in H^+ concentration (resulting in decreased pH)
- Alkalemia: pH > 7.45
- Alkalosis: a process associated with a decrease in H^+ concentration (resulting in increased pH)

2. Role of Acid–Base Status on Oxygenation[2]

Oxygen's ability to bind to hemoglobin depends on many factors. Acid–base status and temperature are 2 factors that can impact oxygen saturation (Figure 4-1). Acidemia decreases oxygen's affinity for hemoglobin and may thus slightly increase the partial pressure of oxygen (PO_2). Alkalemia increases oxygen's affinity for hemoglobin and thus results in a decrease in the PO_2.

3. Regulation of H^+ Concentration[1,2]

Most physiologic H^+ originates as by-products or end-products of cellular metabolism. The concentration of H^+ must be tightly regulated to maintain a pH compatible with

CHAPTER 5

Common Clinically Applicable Situations

Numerous diseases and situations encountered in clinical practice affect fluid, electrolyte, and acid–base homeostasis. Clinicians must identify these situations, understand organ physiology and disease pathophysiology, and develop management strategies to prevent morbidity and mortality. This chapter will focus on renal, hepatic, and gastrointestinal (GI) disorders; hyperglycemic emergencies; refeeding syndrome; and adrenal insufficiency. It will also include each condition's effects on fluid, electrolyte, and acid–base homeostasis.

Renal Failure

Overview[1–3]

The kidneys play an integral part in many key functions in the body, including regulation of blood pressure, gluconeogenesis, hormone production, and vitamin D activation; removal of waste products; elimination of drugs, drug metabolites, and toxins; electrolyte homeostasis; and maintenance of acid–base and fluid balance. The kidney's ability to perform many of its functions depends on intact filtration, reabsorption, and secretion.

Much of renal physiology is focused at the nephron level. The kidney has approximately 1 million nephrons. The nephron serves as the functional unit of the kidney. Each section of the nephron is responsible for specific actions. Blood begins to be filtered at the glomerulus. As this filtrate travels through the nephron, certain substances are reabsorbed while others are secreted to maintain homeostasis (see Table 1-6). When renal injury occurs, abnormalities in fluid, electrolyte, and acid–base homeostasis can develop. These complications can be predicted and explained physiologically by knowledge of the type and magnitude of the renal injury or disease.

Disorders of the kidneys are classified according to the onset and length of renal impairment. The 2 major disorders are acute kidney injury (AKI) and chronic kidney disease (CKD).

Acute Kidney Injury[2,4–7]

- AKI is defined by the sudden decline in renal function occurring over a period of 48 hours to 7 days. AKI may be reversible if the offending condition is corrected or agent is removed.
- AKI is reported to occur in up to 20% of hospitalized and 45% of critically ill patients. Morbidity and mortality are significantly higher in patients that develop AKI vs those without AKI, with an associated mortality rate ranging from 30% to 80%. The magnitude of renal injury directly correlates with mortality and the need for renal replacement therapy (RRT).

CHAPTER 6

Pediatric Considerations for Fluid, Electrolyte, and Acid–Base Disorders

Fluid, electrolyte, and acid–base management in the pediatric patient continues to be a challenge for many practitioners. Chapters 1–5 provide an excellent framework for the diagnosis and treatment of fluid, electrolyte, and acid–base disorders; however, pediatric patients require special considerations. This chapter will cover considerations for fluid, electrolyte, and acid–base disorders specific to the pediatric patient.

The pediatric patient population encompasses a variety of patient types from premature neonates, term neonates, infants, and small children to adolescents. This patient diversity results in a corresponding variability in fluid requirements. As the patient ages, the percent total body water (TBW) decreases from about 85% in the preterm neonate to 60% in the adolescent. As the TBW decreases, a corresponding decrease in fluid volume per body weight is seen.[1–4] Patients with higher TBW also tend to develop fluid/electrolyte imbalances more frequently than patients with lower TBW. Daily fluid requirements can be estimated in a variety of ways. One of the most common ways, the Holliday-Segar formula, is a weight-based method (Table 6-1). Using this formula, a child weighing 27 kg would require a minimum of 1640 mL of fluid per day.

100 mL/kg for first 10 kg =	100 × 10 =	1000 mL
50 mL/kg for next 10 kg =	50 × 10 =	500 mL
20 mL/kg for weight > 20 kg =	20 × 7 =	140 mL
TOTAL		1640 mL

This formula, however, does not address fluid requirements in patients with disease states such as kidney failure or congestive heart failure that alter fluid accumulation.[5,6]

Hypovolemia is a condition in which TBW is decreased significantly enough to cause signs and symptoms such as dry mucous membranes, tachycardia, and if conditions worsen, hypotension and orthostasis. The causes and treatment of hypovolemia in adult patients are covered in chapter 2. In addition to the causes for hypovolemia seen in adult patients, those more specific to pediatric patients include vomiting, diarrhea, excessive sweating, and inad-

TABLE 6-1. Calculating estimated fluid requirements (Holliday-Segar formula).

Body weight	Daily fluid requirement (Holliday-Segar)	Fluid requirements (4:2:1 short cut)
≤ 10 kg	100 mL/kg	4 mL/kg/h[a]
> 10 kg to ≤ 20 kg	1000 mL + 50 mL/kg for wt > 10 kg	40 mL/h + 2 mL/kg for wt > 10 kg
> 20 kg	1500 mL + 20 mL/kg for wt > 20 kg	60 mL/h + 1 mL/kg for wt > 20 kg

wt, weight.

[a]This may underestimate fluid requirements by about 5% in young children. 5 mL/kg/h is often used to avoid this.