TEXTBOOK OF

Urinalysis and Body Fluids

Doris L. Ross

Ann E. Neely

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This textbook is dedicated to:

Violet Keiller, M.D., Martha Gregg, M.T. (ASCP),
and Twila McIntire, M.T. (ASCP),
who first taught me urinalysis.
Doris Ross

And to:

The authors' families
Ann E. Neely
Kathryn Kilpatrick Cheek

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PREFACE

ALTHOUGH SEVERAL good books on urinalysis are available to the clinical laboratory scientist, none covers exclusively urinalysis and body fluids in one volume. This separation makes it difficult for the student of clinical laboratory sciences to recognize the common factors responsible for the abnormalities in these fluids. Our textbook is designed to place these related areas together and thus assist in the recognition of the relationships that exist. This relationship is already recognized in programs of medical technology where both subjects are taught by the same instructor in one course.

Much could be written about any one of the topics covered in this book. It has been a challenge to the authors to select information and present it in a way that is most appropriate for an understanding of the practice of urinalysis and the examination of body fluids. One of the most profound rewards of our efforts is the increased respect for writers to whom we refer. It has been our earnest desire that no information has been misread or misinterpreted in the organization of the material and that we have cited the most appropriate source when several were available.

The need for clinically relevant information in the examination of body fluid specimens is clearly evident from the increasing number of specimens submitted to the clinical laboratory. There is currently no one book available that considers the examination and the clinical interpretations related to all the body fluids covered here. The authors of this portion of the book have written the procedures and the clinical interpretations of the body fluids as a ready source for practice and for teaching. Since no other book filled this need the methods of performance of these tests have been included.

The detailed procedures for the performance of the tests on urine, including some of the special tests, have been adequately covered in previous publications on the subject. The urinalysis portion of the book provides the reader with the pathophysiological concepts of the formation of urine as well as the principles and problems encountered in the examination of urine in the clinical laboratory. Some of the information may not be required for the performance of the routine examination of urine; however, these concepts are included for those students who want to learn more than the methods. The authors understand that the time available and the course's particular objectives must determine how the content of this book can be used. Accordingly, the information within the chapters has been arranged so that certain units may be disregarded without confusing the student. Objectives, review questions, and case studies are included to make the study of urinalysis and body fluids interesting and memorable for students in medical technology, medical laboratory sciences, and laboratory medicine.

Appreciation is expressed to the following

for their contribution to the urinalysis part of the book: Dr. Donald C. Cannon, who encouraged this endeavor; Dr. Ruth Bulger and Dr. Regina Verani for their critique and assistance; Mr. David Payne and Mr. Brad Perkins for the art work and photography; and the secretarial staff, all of whom are representative of the support given by the Department of Pathology and Laboratory Medicine of the Medical School; and Dr. Alton Hodges, Dean, and the staff of the School of Allied Health Sciences of the University of Texas Health Science Center at Houston for their support.

Appreciation is also extended to Dr. Jose M. Trujillo, Director, and Ms. Phyllis Sedgewick of the Department of Laboratory Medicine, and Mr. John Kuykendall of The University of Texas M.D. Anderson and Tumor Institute of Houston for the photographs of urinary sediment. For their contributions to the body fluids portion of the book, we are indebted to the following: Ms. Bonnie Szymik and Ms. Betty Blisset for selecting and providing specimens, Dr. Jonathan Kraus for assistance in interpretations of specimens, Dr. David Lehmiller and Dr. Dee McFarland for their initial inspiration, and Ms. Barbara Edwards, all of the Department of Pathology; Ms. Ann Anderson, School of Medical Technology; Dr. Larry Lutcher and Ms. Betty Williams, Department of Medicine, for their assistance and encouragement. Also, Dr. Frank Winekoff for his contribution in organizing material about malignant cell characteristics and guidance in comparative studies of Wright stained and Hematoxylin-Eosin stained specimens; Ms. Leslie Laurens for the illustrations; Mr. Roosevelt Brown, Medical Illustration Services; and Ms. Theresia Renick, Ms. Jenny Moore and Ms. Peggy Salter for typing the manuscript.

We hope that this book will contribute to a better understanding of the examination of urine and body fluids.

TEXTBOOK OF

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CONTENTS

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CHAPTER 1

Fluid Formation in the Body

Objectives

It is expected that the information presented in this chapter will enable the reader to:

1. Identify the forces involved in ultrafiltration from the capillary.
2. Utilize data about Starling's forces to determine the resulting ultrafiltration or reabsorption.
3. Define the term "interstitial fluid."
4. Calculate the ion distribution at equilibrium of solutions on either side of a membrane, one side of which contains nondiffusible protein.
5. Identify the relative water composition of the body spaces.
6. Compare the water content and osmolality of interstitial and intracellular fluid.
7. Explain the difference in ion content between interstitial fluid and blood plasma.
8. Evaluate substances used to determine extracellular water.
9. Distinguish normal from abnormal anionic and cationic composition of extracellular and intracellular fluid.
10. Correlate the body cavity containing the fluid with the appropriate term applied to that effusion.
11. Determine the relationship between conditions of edema and dehydration and the laboratory results that may be anticipated in each case.

The molecular activities of the cells in the human body occur in an aqueous environment. The ebb and flow of this sea within and the alteration of its composition influence and, in turn, are influenced by the metabolic processes that are life sustaining.

Fluid enters the body by ingestion and absorption through the intestinal tract. Some of the body fluid is derived from the oxidation within the tissues. The average individual ingestion of water in the form of liquids and solid foods is about 2.2 L/day. Other sources and ways in which water is lost from the body are shown in Table 1.1.

Once the fluid is absorbed, it becomes a part of the circulating blood plasma. Fluid distribution in the body is determined by blood flow as well as certain forces and cellular functions that occur in the capillaries of the body.

DIFFUSION

The formation of interstitial fluid begins with the process of transudation or ultrafiltration across the endothelial cells of the capillary wall. Ultrafiltration occurs by passage of water, small molecules, and ions through pores at intercellular spaces between the adjacent endothelial cells, through vesicles, or through fenestrae in the cells of the capillary wall. The surface area of capillaries of voluntary and heart muscle in the adult has been estimated to be about 465 m^2 (5,000 sq ft), about 1 sq m (10 to 11 sq ft) of which is lateral spaces between adjacent endothelial cells. These gaps (4 to 6 nm) allow the passage of horseradish peroxidase (40,000 daltons) and limited passage of albumin (65,000 daltons). Some solutes and water may also be actively transported across the capillary endothelial cells. The magnitude of the entire process is such that a volume of fluid equivalent to the entire plasma volume crosses the capillaries in 60 seconds.

One of the forces involved in this process is that described by the Gibbs-Donnan effect. The Gibbs-Donnan rule states that the product of the number of charges of diffusible anions and cations on one side of a permeable membrane will equal the product of the same ions on the other side of the membrane at equilibrium. Therefore, if a nondiffusible anion, e.g., protein (Pr^-) at physiologic pH, is on one side of such a membrane, the diffusible ions will not be distributed equally on either side of the membrane at equilibrium. However, the total cations will equal the total anions within each compartment. An example of this effect is shown in Figure 1.1. It can be seen that the total number of particles on the side containing the protein will be greater, and therefore a greater osmolality will exist on that side.

The osmolalities of the interstitial fluid and intracellular fluid have been determined to be similar. The total concentrations of sodium, potassium, and other solutes will not necessarily be identical in both fluids because osmolality is a colligative property and, thus, is a function of the number of particles in solution. The number of ionic charges has no effect on the osmolality.

Even though the osmolality of the blood plasma is greater than that of interstitial fluid, the size of each compartment is constant in the steady state. A consideration of the forces

TABLE 1.1. WATER IN AND OUT OF THE BODY

Source			Loss		
Fluids of diet	1,200 ml	48%	Lungs	500 ml	20%
Food	1,000 ml	40%	Skin	500 ml	20%
Oxidation in tissues	300 ml	12%	Urine	1,400 ml	56%
			Feces	100 ml	4%

From Hawk PB, Oser BL, Summerson WH: Practical Physiological Chemistry, 13th ed, 1954, p 1080. Courtesy of McGraw-Hill Book Co.

Initial		Equilibrium	
5 Pr^-	10 Cl^-	5 Pr^-	
5 Na^+	10 Na^+	4 Cl^-	6 Cl^-
		9 Na^+	6 Na^+
A	B	A	B

Figure 1.1. The Gibbs-Donnan effect of ion distribution. (Modified from Pitts RF: Physiology of the Kidney and Body Fluids, 3rd ed, 1974. © 1974 Year Book Medical Publishers, Inc., Chicago.)

that play a role in this constant distribution of water between interstitial tissues and the circulating blood plasma led Starling, in 1896, to propose the now classic Starling hypothesis.[1] According to the hypothesis, blood is filtered out of the capillary at the arteriolar end and is returned to the capillary from the interstitial tissue at the venular end (Fig. 1.2). The forces promoting ultrafiltration from the capillary are the hydrostatic pressure due to blood pressure that decreases in the direction of the venule and the interstitial oncotic pressure due to the small concentration of protein in that fluid. The opposing forces are the plasma oncotic pressure and the pressure from the turgidity of the interstitial tissue. The net pressure of approximately 1.4 kilopascal (kPa) at the arteriolar end of the capillary favors ultrafiltration, whereas at the venular end the net pressure of less than 0 favors reabsorption. The excess of the ultrafiltrate enters the lymphatic circulation. Other important factors in the maintenance of plasma and interstitial volume are the activity of the precapillary sphincters in the regulation of hydrostatic pressure, the total surface area, and the permeability of the capillaries.

DISTRIBUTION OF BODY WATER

Water represents 50 to 70 percent of the body weight. Thirty to forty percent of this water is located in the tissue cells, about 16 percent in the interstitial fluid, and about 4.5 percent in the blood plasma (Fig. 1.3). One to three percent is located in the transcellular water of the cerebrospinal, digestive, pleural, synovial, intraocular, and peritoneal fluids.[2] The transcellular fluid is separated from the

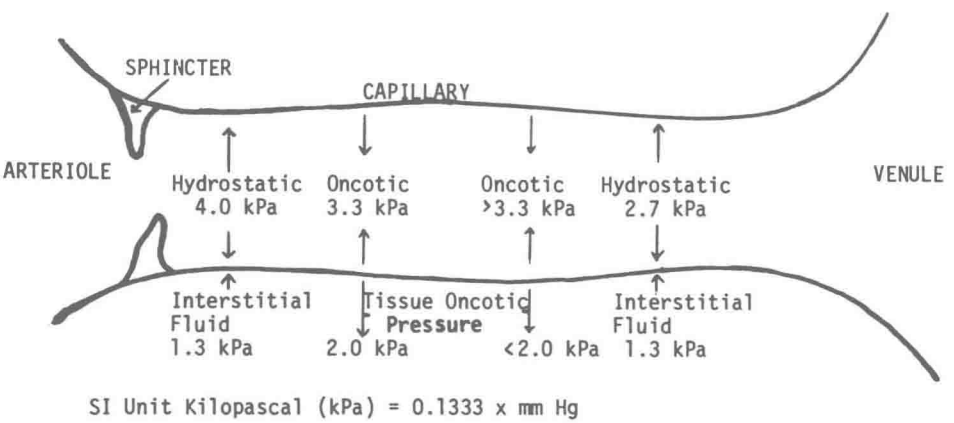

Figure 1.2. Starling hypothesis of forces governing ultrafiltration.

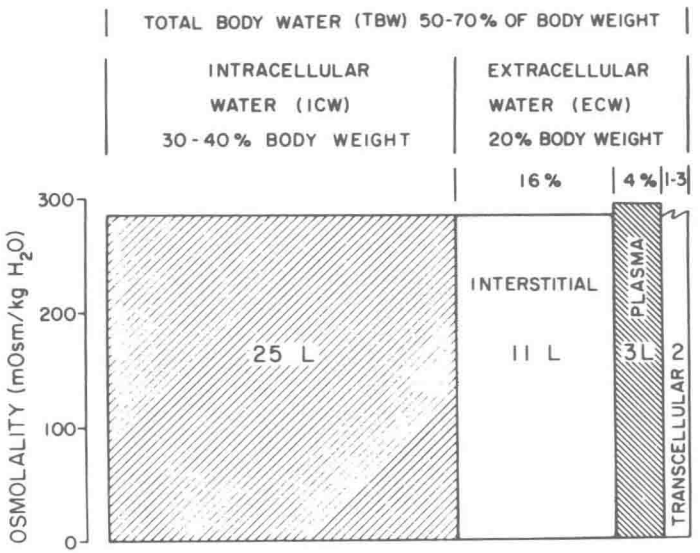

Figure 1.3. Distribution of body water. Approximate sizes of the major body fluid compartments, expressed as percentage of body weight and in mean absolute values for an adult human being who weighs 70 kg (154 pounds). The ranges of normal among individuals are considerable, and thus no one value should be taken too rigidly. The plasma has a slightly higher osmolality than the intracellular and interstitial compartments. This small difference can be ignored when dealing with problems of fluid balance. (From Valtin H: Renal Function: Mechanisms Preserving Fluid and Solute Balance in Health, 1973, p 16. Courtesy of Little, Brown, and Company. Copyright 1973.)

blood by epithelial cells in addition to the capillary endothelial barrier of the other interstitial fluid compartments.

The water content of plasma is 94 percent, and that of intracellular fluid is 75 to 80 percent. For the entire body, the water content is measured by administering a substance that will become distributed throughout all compartments of body fluids. Such substances are antipyrine and deuterated or tritiated water. The dilution of the substance is measured by spectrophotometry or by its radioactivity in the blood plasma after time for equilibration in the compartments has elapsed. The concentration of the substance in the plasma is computed, taking into account the loss through the urine, the breath, and the skin.

Extracellular water is measured by using substances that do not penetrate cell membranes. Inulin, sucrose, and thiocyanate have been used for this purpose. Plasma water is determined using radiolabeled albumin, red cells, or Evans blue dye. These substances do not allow accurate quantitation, since the albumin and also the Evans blue dye that is bound by albumin will cross the capillary endothelium to a limited degree and enter the interstitial compartment. Methods utilizing red cells also have some inaccuracy because of the uneven distribution of these cells in the plasma of small capillaries. No substances that will become selectively distributed in the interstitial and intracellular compartments have been identified. However, the interstitial space can be calculated as the difference between the extracellular water and the plasma water. The intracellular space can be calculated as the difference between the total body water and the extracellular water.

SOLUTES IN THE FLUID COMPARTMENTS

Sodium is the cation and bicarbonate is the anion of greatest concentration in the extra-

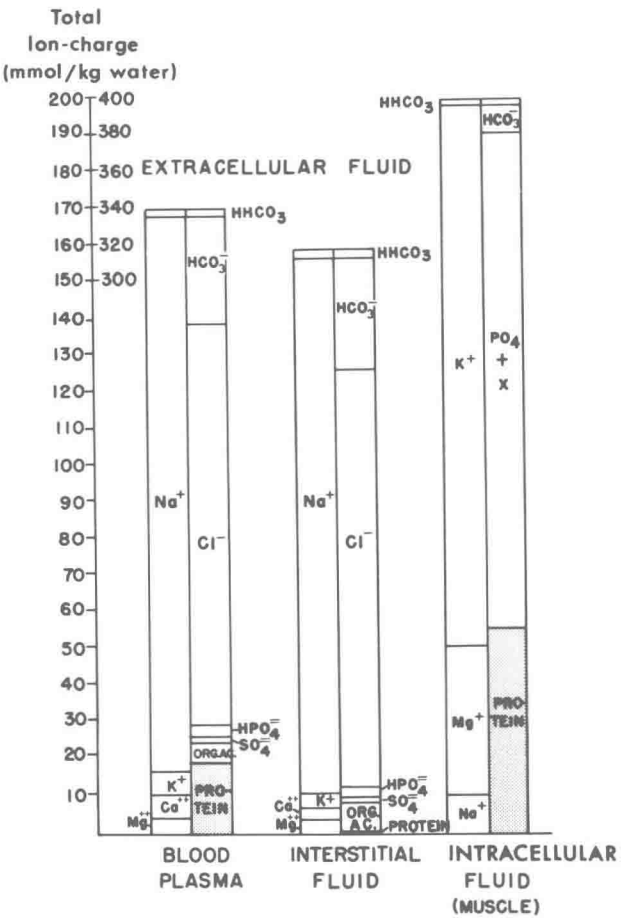

Figure 1.4. Electrolyte composition of blood plasma, interstitial fluid, and intracellular fluid. (From Tietz N, Siggaard-Anderson O: Fundamentals of Clinical Chemistry, 1976, p 948. Courtesy of W.B. Saunders Co.)

cellular fluid. Potassium and magnesium are the cations of greatest concentration in the intracellular fluid, while proteins and organic phosphates are the principal anions. The major difference between the plasma solutes and those of the interstitial fluid is the greater concentration of proteins in the plasma. The barrier of capillary endothelium that prevents protein transport from one compartment to the other establishes a Gibbs-Donnan effect that results in a 5 percent gap between the concentration of diffusible ions in these two compartments (Figs. 1.3, 1.4).

Cells can adjust a difference in osmotic pressure across the membrane by using active transport methods. The distribution of diffusible ions can be practically explained by the effect of the sign and charge of the membrane potential. The explanation is useful when the uneven distribution of the chloride ion in red cells and plasma is considered. Sodium distribution, however, cannot be explained by the membrane potential. Its distribution is explained by an active transport