REGULATION OF EXTRACELLULAR FLUID VOLUME AND OSMOLALITY

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In health, both the total amount and the distribution of water and electrolytes in the body are controlled within narrow limits. While intercompartmental water fluxes depend solely on physical driving forces, the latter are determined by complex circulatory feedback mechanisms that manipulate capillary pressure, and by active transport mechanisms that affect intracellular osmotic pressure. Fluid and electrolyte intake are determined by central neural mechanisms. However, the fine tuning of body fluid and electrolyte contact is accomplished by alterations in renal excretion controlled by a variety of local (intrarenal) mechanical and endocrine processes, as well as external neural endocrine feedback systems that include the antidiuretic hormone and the renin-angiotensin-aldosterone systems. Analysis of renal control is complicated by multiple interactions among the different control systems.

This discussion will be limited to a review of the factors that control extracellular volume and osmotic content in the normal human. Rather than go into the details of the various system transfer functions, I hope to emphasize some of the control strategies that appear to have guided the design of the system.

Since the following articles in this section will emphasize hemodialysis, it is tempting to draw comparisons between the control of fluid volume and composition in the body with the process control techniques used to regulate the composition and flow or volume of dialysate fluid. Such a comparison might suggest that the control of body fluids is a trivial process, when in reality the biological control system is extremely complex. It encompasses a wide variety of passive and active elements, employs multiple different sensors to obtain direct and indirect estimates of changes in the controlled variables, and encompasses several complicated, interacting neuroendocrine feedback loops.

This high order of redundancy reflects the extreme importance to the
organism of maintaining proper extracellular fluid balance and osmotic concentration. The need for an appropriate extracellular fluid (ECF) osmolality is implicit in the concept that the ECF provides the environment for all of the body's cells. The requirement for a well regulated ECF volume arises from the fact that one component of that volume, the blood plasma (and the cellular components contained therein) are the working fluid for the cardiac pump. Either an inadequate ECF volume, e.g., as a result of hemorrhage, or an excessive volume, as in congestive heart failure, can lead to or be associated with cardiac pump failure. The essential end result is the same in both cases—inadequate tissue perfusion with consequent disturbances in ECF and intracellular composition. Thus, the ECF volume plays a crucial role in determining its own, as well as intracellular, composition.

THE BODY FLUID COMPARTMENTS

Figure 1 shows the relationship of the ECF volume to the other body fluid compartments. Water and solute exchange between the vascular and interstitial compartments occurs rapidly by ultrafiltration and diffusion,