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Interstitial Fluid: It Speaks Volumes

Medical Materials & Technologies

Interstitial fluid is having a moment.

Today's patients and providers want information immediately, and interstitial fluid can deliver. In fact, interstitial fluid often gives insight into conditions before blood can. In this paper, we'll look at interstitial fluid's diagnostic capabilities– but first let's learn what interstitial fluid is and how it is formed in the body.

Interstitial Fluid: It Speaks Volumes

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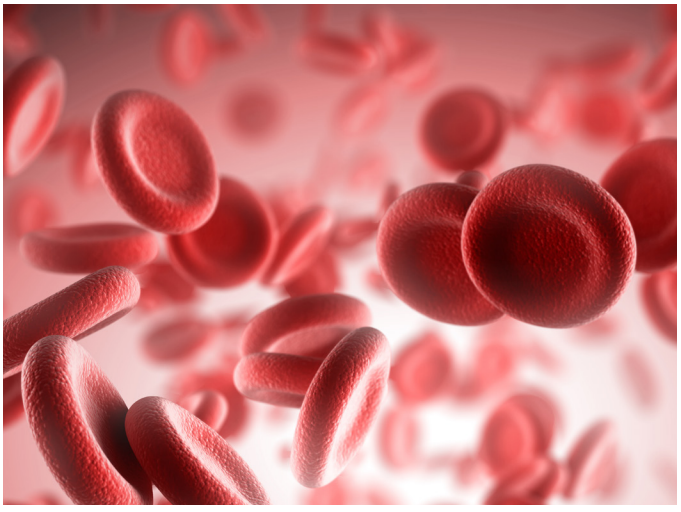
What is interstitial fluid?

Our body distributes about 40 liters (about 10 gallons) of fluid in three main fluid "compartments:" intracellular fluid (28 liters), blood (4.6 liters), and interstitial fluid (9.4 liters).[1]

As blood flows from the heart and lungs through an artery [arteriole] then through a capillary and into a vein [venule] to return to the heart, a small amount of water moves from the blood into the spaces between cells, i.e., into the "interstitial spaces." This "interstitial fluid" results from an interplay between hydrostatic and osmotic pressure. The heart puts hydrostatic pressure on blood vessel walls as it pumps blood through the circulatory system. Hydrostatic pressure pushes water outward and into the spaces between the cells [interstitium] through tiny openings in the capillary vessel wall. The osmotic pressure, exerted in opposition to the hydrostatic pressure, is due largely to the presence of protein in the blood, and it is constant along the length of the capillary. At the arteriole end of the capillary, hydrostatic pressure is greater than osmotic pressure, so water moves through the capillary wall into the interstitial spaces. Then, at the venule end of the capillary, the hydrostatic pressure has dropped to a value that is less than the osmotic pressure, and most of the water from the interstitial space returns to the blood inside the capillary. The relatively small amount of fluid that remains in the interstitial space, the interstitial fluid, also called lymph, bathes the cells and eventually returns to the blood via the lymph vessels that empty into the circulatory system near the heart.[1]



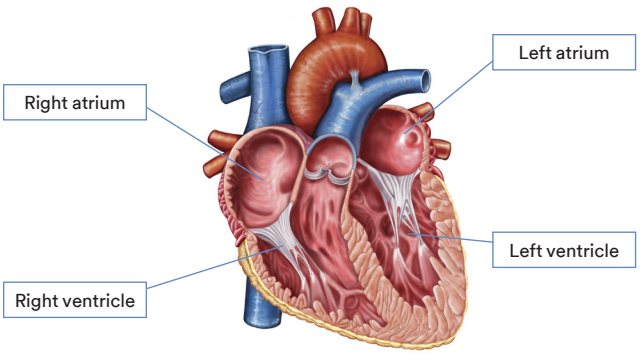
What causes changes in interstitial fluid volume?

Nutritional status and certain diseases affect interstitial fluid volume and composition. For example, in many cases malnutrition, blood protein content falls, thus reducing osmotic pressure in the capillary; this, in turn, results in greater volume of interstitial fluid, which can accumulate in the abdomen ("ascites" or swollen belly). It can even manifest as visible fluid seepage though the skin, especially if the skin is fragile. On the other hand,

when the heart fails, as in congestive heart failure, fluid "backs up" in the vessels due to the heart's pumping inefficiency. Right-sided heart failure can cause the back-up of fluid in the vessels raising blood pressure in the extremities. Left-sided heart failure can cause interstitial fluid to accumulate in the extremities and the lungs.[2]

What causes changes in interstitial fluid composition?

The content of various substances in interstitial fluid is influenced by a number of factors including, the nature of neighboring tissue. Thus, the protein content of interstitial fluid depends on regional differences in capillary permeability.[3] Tissues that do not receive an adequate supply of oxygen produce lactate. Lactate is detectable in blood and is used for diagnosis of sepsis, but lactate also builds in the interstitial fluid, may serve as an early marker of sepsis.



Right Sided Heart Failure: Poor pump efficiency of right ventricle causes fluid to back up in incoming veins, thus increasing hydrostatic pressure and resulting in increase in volume to interstitial fluid.

Is there diagnostic value in sensing interstitial fluid?

There is increasing interest in using interstitial fluid for patient assessment and diagnosis of disease, especially in the critical care arena.4 Reasons for renewed interest include the notion that blood analysis from critically ill patients provides a "global" average assessment of the patient, while analysis of regional interstitial fluid offers information about the patient's current status before information is revealed in a blood analysis specimen. For example, it is important to monitor congestive heart failure patients for worsening disease, "decompensation", so that medications such as diuretics can be adjusted. Current monitoring methods for these patients depend largely on daily weight, but weight can fluctuate with calorie intake. Detecting increasing interstitial fluid (edema) in ankles can alert the health care worker of worsening disease or cardiac state.

Similarly, blood lactate levels rise in sepsis due to poor tissue perfusion, but high blood lactate commonly can't be detected until much later – when this often-fatal condition has progressed. Some research has aimed to assess lactate in interstitial fluid of organs (such as stomach mucosal tissue) and regions of the body that can serve as early warning signs for sepsis.5

One could envision a skin sensor for detecting interstitial fluid volume and content to monitor nutritional status in at-risk individuals, such as the elderly.

What technologies are needed to prepare interstitial fluid sensors?

Aside from communicating sensor data to the reader – so sensor data can be collected, analyzed, and stored – interstitial fluid sensors require two main components. First, the sample must be able to be collected or monitored in situ. Microneedles have shown some promise in withdrawing interstitial fluid from skin. Other devices, such a recently commercialized 14-day glucose-monitoring system, enable in situ monitoring of glucose in interstitial fluid. Second, for extended real-time monitoring of interstitial fluid volume or content, high skin adhesion is necessary, so an abbreviated wear time (due to poor adhesion) does not limit usage, and so the sensor doesn't inhibit activity and bathing.

References:

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