Interstitial Hydrostatic Pressure: a Manual for Students

During the learning of capillary fluid traffic, students are often puzzled about the negative values found in their textbooks for interstitial pressures in subcutaneous tissue and lungs (4, 6). Positive pressures are reported for the brain, kidneys, and liver (6) and particularly in various tumors (3). Although the reported values differ, pressures probably range from −8 mmHg in the lungs to −3 or −2 mmHg in subcutaneous tissue to 0, +1, and +2 mmHg in the liver and kidneys or +6 mmHg in the brain (4, 6). Interstitial pressure can reach very high positive values in tumors (from 20 to >40 mmHg) (2, 3). Reported findings in freshly burned tissue describe even more positive values in tumors (from 20 to >80 mmHg) (2, 3). The draining process is augmented by the physical work of neighboring muscles in subcutaneous tissue or by breathing. Negative values are normally found only in lungs and subcutaneous tissue. These are the only two body parts freely compressed by outside air pressure. In both tissues under normal perfusion, outflow capacities (venous blood and lymph) are greater than needed for the inflow volume and capillary permeability. Large outflow capacities drain most of the interstitial water and reduce its hydrostatic pressure to 0.

I. The draining process is augmented by the physical work of neighboring muscles in subcutaneous tissue or by breathing.

II. Muscle contractions compress and evacuate lymph vessels. The flow is centripetal because of lymph valves. Thus, negative subcutaneous pressures might develop ex vacuo, after tissue compressions by muscles, if intact valves in lymph vessels are able to prevent lymph flow back to the uncompressed tissue.

III. We can try to simplify this concept by looking at different organs and tissues in more detail (Table 1).

A. All organs with positive interstitial hydrostatic pressure are more or less space confined and lack any content of compressible gases. Fluid traffic in them must be balanced, inflow volumes must equal outflow volumes, and the interstitial hydrostatic pressure can be considered to be a result of outflow resistance.

1. For instance, kidney interstitial pressure will rise in urinary tract obstruction, in lymphatic obstruction, in perirenal compression due to injury, etc. Less outflow resistance leads to lower positive values of interstitial pressure in confined organs.

B. Negative values are normally found only in lungs and subcutaneous tissue. These are the only two body parts freely compressed by outside air pressure. In both tissues under normal perfusion, outflow capacities (venous blood and lymph) are greater than needed for the inflow volume and capillary permeability. Large outflow capacities drain most of the interstitial water and reduce its hydrostatic pressure to 0.

As educators, we are continually designing new methods and procedures to enhance learning. During this process, good ideas are frequently generated and tested, but the extent of such activities may not be adequate for a full manuscript. Nonetheless, the ideas may be quite beneficial in improving the teaching and learning of physiology. Illuminations is a column designed to facilitate the sharing of these ideas (illuminations). The format of the submissions is quite simple: a succinct description of about one or two double-spaced pages (less title and authorship) of something you have used for the classroom, teaching, laboratory, conference room, etc. You may include one or two simple figures or references. Submit ideas for inclusion in Illuminations directly to the Associate Editor in charge, Stephen DiCarlo (sdicarlo@med.wayne.edu).

### Table 1. Characteristics of organs and tissues that influence their interstitial hydrostatic pressure

<table>
<thead>
<tr>
<th>Organ or Tissue</th>
<th>Space Confinement</th>
<th>Gas Content</th>
<th>Interstitial Hydrostatic Pressure</th>
<th>Inflow Volumes</th>
<th>Outflow Volumes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brain</td>
<td>Yes (skull)</td>
<td>Abundance of air in lungs</td>
<td>Positive</td>
<td>Yes</td>
<td>Expiring air</td>
</tr>
<tr>
<td>Lungs</td>
<td>Yes (anatomically due to the thoracic cavity and No (at the tissue level due to free air flow))</td>
<td>No</td>
<td>Negative</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Liver</td>
<td>Yes (capsule)</td>
<td>No</td>
<td>Positive</td>
<td>Yes Portal blood</td>
<td>Yes Bile</td>
</tr>
<tr>
<td>Kidneys</td>
<td>Yes (capsule)</td>
<td>No</td>
<td>Positive</td>
<td>Yes</td>
<td>Urine</td>
</tr>
<tr>
<td>Subcutaneous or submucosal tissue</td>
<td>No (compressible by external air pressure)</td>
<td>Abundance of surrounding air</td>
<td>Negative</td>
<td>Yes</td>
<td>Yes No</td>
</tr>
</tbody>
</table>

*Brain interstitial fluid absorption is through the lymphatic-like action of the perivascular spaces (6), whereas some cerebrospinal fluid probably enters through paranasal lymph routes (7).
in lung tissue. In both cases, tissue movements and pressure changes help blood and lymph to leave the tissue.

2. Tissue structures are deformed by the pressure of outside air. Cellular and interstitial structures tend to obtain a shape and position of minimal energy. Their recoil forces “stretch” the well-drained interstitial space and reduce the hydrostatic pressure in it to sub-zero values, so sub-zero values of hydrostatic pressure in small tissue volumes can result from forces of recoil of the cellular and interstitial structures around it. An optimal shape and position of tissue structures can be achieved only in edematous tissue when the interstitial pressure becomes positive due to compromised fluid outflow. (7)

REFERENCES


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