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 negative interstitial pressures that can reach −20 to −30 mmHg (8).

During seminars on capillary dynamics, teachers are often asked to clarify the whole concept in a brief explanation. One of the possible interpretations, in a form of a manual for students, is presented here. The Croatian edition of Guyton and Hall’s textbook (6) was used as the main reference.

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I. Reported interstitial pressures range from −8 to +6 mmHg in different tissues and from less than −20 mmHg in burned tissue or more than +30 mmHg in tumors. The negative interstitial pressures in subcutaneous tissue and other tissues are usually attributed to the action of lymphatics (1, 6). It was stated by Guyton and Barber (5) that “...the only probable source of energy that could create the negative hydrostatic pressure in the free fluid and the equivalent negative chemical potential in the intragel fluid is a lymphatic suction pump. Unfortunately, the existence of this has not yet been proved, but mechanisms by which the terminal lymphatic system could act as a suction pump have been proposed.”

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.

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

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>No</td>
<td>Positive</td>
<td>Yes</td>
<td>Yes</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>Abundance of air in lungs</td>
<td>Negative</td>
<td>Yes</td>
<td>Yes *</td>
</tr>
<tr>
<td>Liver</td>
<td>Yes (capsule)</td>
<td>No</td>
<td>Positive</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Kidneys</td>
<td>Yes (capsule)</td>
<td>No</td>
<td>Negative</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Subcutaneous or submucosal tissue</td>
<td>No (compressible by external air pressure)</td>
<td>Abundance of surrounding air</td>
<td>Positive</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Negative</td>
<td>Yes</td>
<td>Yes</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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