Aspiration-Assisted End-Cut Coaxial Biopsy Needles

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Abstract
A new end-cut-type coaxial needle with a modified aspiration mechanism has been developed to extract large tissue with minimal damage. The study shows that the clearance between the inner stylette and external needle and the insertion speed are the key factors affecting the biopsy performance including syringe friction force and amount of tissue extracted. This research presents the design and manufacture of the system, protocol to evaluate the needle biopsy, and evaluation of the needle biopsy performance using gelatin and chicken breast as tissue samples.

Schematic of biopsy system

(a) Coaxial needle is inserted in tissue
(b) External needle moves forward and cuts tissue
(c) External needle stops then a block is placed to hold tissue
(d) Coaxial needle is removed with extracted sample from tissue

Developed biopsy system

Force measurement

\[ F = \begin{cases} F_t : & \text{total force} \\ F_c : & \text{cutting force the needle tip} \\ F_f : & \text{friction force between tissue and wall of the external needle} \\ F_{ft} : & \text{friction force between tissue and the external needle} \\ F_{fr} : & \text{friction force between the coaxial needle} \\ F_{rr} : & \text{friction force between the rubber plunger and syringe barrel} \end{cases} \]

Experimental conditions

<table>
<thead>
<tr>
<th>Needle size</th>
<th>18 Gauge (OD: 1.27 mm; ID: 1.14 mm)</th>
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</thead>
<tbody>
<tr>
<td>Total insertion length (mm)</td>
<td>40</td>
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<tr>
<td>Biopsy length (mm)</td>
<td>25</td>
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<tr>
<td>Needle clearance (µm)</td>
<td>50, 75, 100</td>
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<tr>
<td>Needle insertion speed (mm/s)</td>
<td>1, 5, 10</td>
</tr>
</tbody>
</table>

Biopsy Experiments (Chicken Breast)

With no aspiration assistance

Without aspiration assistance

With aspiration assistance

Conclusions

1. The developed system collects samples, with a zero biopsy rate of 0%, by means of simultaneous cutting and aspiration of the coaxial needle assemblies.
2. The needle-tissue phantom interaction force decreases with increasing inner stylette diameter and needle insertion speed.
3. Coaxial needles with less clearance yields a larger and better shaped sample with less force required. However, faster needle insertion does not lead to a large sample extraction due to the greater influence of the sample deformation.
4. The biopsy tests using inhomogeneous chicken breast samples also showed the same trend: lower needle insertion speeds facilitate sample collection. However, the extracted samples contain more solid and less solid. To increase the ratio of solid to liquid, higher needle insertion speeds are required.


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