Fiducial Shift Error Consequences in Image Guided Endonasal Surgery

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Abstract
Anecdotally, surgeons observe large errors when using image guidance in endonasal surgery[1,2]. For example, a previous report of 35 sinus surgery cases found movement of a Brainlab headband (Figure 1-Right) in 14% of cases[1]. The problem arises if the rigid body attached to the patient’s head moves after the registration has been accomplished, because the Image Guidance System (IGS) assumes a rigid connection between the skull and the rigid body.

What is the problem?
A studio[3] shows how the Target Registration Error (TRE) of the Brainlab headband could get worse until around 5.7 mm when one kilo is applied in some direction (Figure 1).

General Experiment Description
An experienced skull base surgeon (co-author MD. Russell) was asked to drill out a simulated hard tumor inside the sphenoid sinus, twice. In each drill out, he will use a different TRE value, one to symbolize the usage of Brainlab headband and the another the usage of a new device based on Granular Jamming [3]. In Figure 2 there is a general description of the different parts of the experiment.

Part 1: Phantom Generation
The skull of a real patient was segmented and the sphenoid sinus was filled in to simulate a hard tumor. Two equals models was printed using a 3D printer with plastic material.

Part 2: Drilling the Phantom
The surgeon started the drilling and he was forced to use the IGS since the tumor and the bone were the same color and material. He started with a initial TRE less than 1 mm but the TRE was deteriorated during the experiment without the surgeon knowledge. The surgeon repeated the same procedure twice using different TRE values in each case.

Part 3: Obtaining the results
The volume drilled was calculated following this procedure (Figure 4): (A) Capturing the drilled tumor surface points with a calibrated ConoProbe[4,5] (which are illustrated in (B)), (C) using the Iterative Closest Point algorithm to register the physical model to the virtual model, and (D) generating the mesh with the Poisson Surface Reconstruction algorithm that defines the boundary where the drilling ended.

Results

<table>
<thead>
<tr>
<th>Case</th>
<th>Surgery Time</th>
<th>Initial TRE</th>
<th>Final TRE</th>
<th>Volume Resected</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Headband</td>
<td>20 min</td>
<td>0.58 mm</td>
<td>5.47 mm</td>
<td>2604 mm³</td>
<td>32.98%</td>
</tr>
<tr>
<td>GHJ</td>
<td>15 min</td>
<td>0.79 mm</td>
<td>3.53 mm</td>
<td>5770 mm³</td>
<td>73.07%</td>
</tr>
</tbody>
</table>

Conclusions & Discussion
The accuracy of image navigation depends on not only registration accuracy, but also on how solidly the reference rigid body can be affixed to the patient’s anatomy. Surgeons can drill more accurately and safely when they have a better TRE. The standard fiducial fixation methods are easily and often displaced. This can lead to a wide discrepancy between what surgery is intended and what is actually performed. Granular jamming is a non-invasive fiducial fixation technique that can improve surgical outcomes.

References