We produced a workflow for evaluating tissue KF led data collection process, SL led postoperatively, as well as postoperative image processing:
- Registration of intraoperative tracking data to preoperative image data and registration of preoperative images to postoperative images.
- In effect, we have addressed the problem of providing better guidelines to radiation oncologists on where to deliver postoperative radiotherapy, allowing decreased radiation poisoning.

### The Problem
- Patient receives surgical resection of tumor and postoperative radiotherapy of surgical bed.
- Volume of radiotherapy overestimated → toxicity and negative physiologic reactions.
- Need method to evaluate tissue deformation after surgery to decrease volume and increase specificity of radiotherapy.

### The Solution
- Take three CT scans of patient: preop, postop with open wound, postop after wound closed.
- Outline pathology with points using Polaris tracking system; register these points to preop CT.
- Using open source medical imaging software, Elastix, to register preop scan to each postop scan.
- Use Transfomix to monitor points' movement.
- Guides postop radiotherapy planning.
- Experimental methodology:
  - In 3 pig heads, a portion of the tongue was removed simulating surgical resection of tumor.
  - 5 fiducials were placed on the surface of the head to determine intraop to postop registration.
  - Placed 4 radio-opaque markers on tongue where Polaris points were collected for gold standard.
  - Removed markers from CT images.
  - Determined optimal Elastix parameters for best possible image registrations.
  - Computed RMS errors between measured fiducials and computed fiducials, and between gold standard markers on tongues and computed tongue points.

### Credits
- KF led data collection process, SL led intraop registration process, MH led image registration process.

### Introduction
- We thank our mentors for their guidance and funding, as well as Seth Billings for helping us obtain the Polaris.

### Outcomes and Results
- Left two images: Registration of intraop Polaris to preop.
- Right two images: Registration of intraop Polaris to postop open.

<table>
<thead>
<tr>
<th>Pig</th>
<th>Clip 1</th>
<th>Clip 2</th>
<th>Clip 3</th>
<th>Clip 4</th>
<th>Total</th>
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<td>11.4</td>
<td>13.1</td>
<td>29.6</td>
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<table>
<thead>
<tr>
<th>Avg RMS (Deform) (mm)</th>
<th>Avg Fiducial RMS (Rigid) (mm)</th>
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<tr>
<td>STD, AMS2</td>
<td>20.14</td>
<td>20.68</td>
</tr>
<tr>
<td>STD, AMS fixed pts</td>
<td>7.47</td>
<td>18.92</td>
</tr>
</tbody>
</table>

- Table above shows accuracy of intraop registration via total RMS error between pre- and postop open fiducials and postop open tongue points.
- Fiducials and markers had diameters of approximately 5 mm.
- Registration of fiducial points onto both scans is very accurate.
- Inherent uncertainty as tongue points on preop scan can be found in unlikely places (off of the tongue) due to movement; creates complications for direct placement of Polaris points on preop scan.

- Table above shows accuracy of registration using the orig. method of preop to postop closed via RMS of tongue clips and total RMS.

<table>
<thead>
<tr>
<th>Parameter Set:</th>
<th>Avg Fiducial RMS (Rigid) (mm)</th>
<th>Avg Tongue RMS (Deform) (mm)</th>
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<td>STD, AMS, fixed pts</td>
<td>7.47</td>
<td>18.92</td>
</tr>
</tbody>
</table>

- Table above shows RMS error resulting from different parameter sets when postop open is registered to preop and then subsequently registered to postop closed; greater accuracy.
- Images below visually show accuracy of this registration method.

### Lessons Learned
- Inherent error in method: Collecting points around tongue intraoperatively, but intraop tissue doesn’t line up with tissue in preop image.
- Necessity to think through entire project and pre-define what data we need and what we need to do with it.

### Future Work
- Explore rigid landmark-based registrations.
- Improve marker positions by placing them on surface of tongue, not protruding and creating error.

### Support by and Acknowledgements
- We thank our mentors for their guidance and funding, as well as Seth Billings for helping us obtain the Polaris.