Disclosure

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Background

- Seed based snapshots
- Non-ionizing seed based
- Real time
- Non-ionizing
- Non-invasive
- Real time

Background

• US is portable, non-invasive, and non-ionizing modality for daily setup and real time monitoring

US challenge 101

- Who is going to hold the probe during radiation?
- Prostate
- Liver
- Pancreas
US challenge 102

Can the probe be placed in a repeatable way?

Liver  
Prostate  
Pancreas

Two solutions

Passive arm (arm bridge system)  
+ Small size  
+ Easy docking  
- User dependent

Active robotic arm (UR5)  
+ Less user dependent  
+ Feedback loop  
- Complex docking

Arm bridge system (ABS)
Arm bridge system (ABS)

Probe impact on planning
### Probe impact on planning

#### Step n shoot

![Step n shoot images](image)

#### VMAT

![VMAT images](image)

#### Clinical

![Clinical images](image)

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### Probe impact on planning

<table>
<thead>
<tr>
<th>PTY</th>
<th>Clinical</th>
<th>Probe ss</th>
<th>P(1)</th>
<th>P(2)</th>
<th>P(3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>D95 (dose to 95% of the PTV) [cGy]</td>
<td>3168±121</td>
<td>3165±78</td>
<td>0.082</td>
<td>3165±80</td>
<td>0.489</td>
</tr>
<tr>
<td>D_mean (mean dose to PTV) [cGy]</td>
<td>3781±465</td>
<td>3706±43</td>
<td>0.084</td>
<td>3716±62</td>
<td>0.283</td>
</tr>
<tr>
<td>D95 (dose to 95% of the PTV) [cGy]</td>
<td>82.6±6.0</td>
<td>91.5±1.4</td>
<td>0.787</td>
<td>83.3±1.3</td>
<td>0.690</td>
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<tr>
<td>Volume of 33Gy + [cm³]</td>
<td>83.4±29.7</td>
<td>86.4±31.3</td>
<td>0.195</td>
<td>82.2±30.5</td>
<td>0.797</td>
</tr>
<tr>
<td>CI (conformal index)</td>
<td>1.08±0.07</td>
<td>1.04±0.06</td>
<td>0.070</td>
<td>1.09±0.08</td>
<td>0.396</td>
</tr>
<tr>
<td>D5 (dose to 5% of the PTV) [cGy]</td>
<td>4122±124</td>
<td>4020±96</td>
<td>0.020</td>
<td>4043±118</td>
<td>0.387</td>
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<tr>
<td>HI (homogeneity index)</td>
<td>0.25±0.05</td>
<td>0.23±0.03</td>
<td>0.187</td>
<td>0.23±0.03</td>
<td>0.600</td>
</tr>
<tr>
<td>V15 (cc) duo</td>
<td>5.66±2.00</td>
<td>6.01±2.17</td>
<td>0.172</td>
<td>5.24±2.13</td>
<td>0.371</td>
</tr>
<tr>
<td>V15 (cc) sto</td>
<td>6.00±2.54</td>
<td>6.12±2.94</td>
<td>0.225</td>
<td>6.22±2.86</td>
<td>0.618</td>
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<tr>
<td>V15 (cc) bowel</td>
<td>6.09±2.05</td>
<td>5.78±2.00</td>
<td>0.270</td>
<td>4.64±1.99</td>
<td>0.464</td>
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<tr>
<td>V15 (cc) liver</td>
<td>6.18±5.01</td>
<td>7.02±6.91</td>
<td>0.312</td>
<td>6.96±7.06</td>
<td>0.467</td>
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<tr>
<td>V15 (cc) stomach</td>
<td>7.51±4.26</td>
<td>7.81±3.67</td>
<td>0.439</td>
<td>6.47±3.30</td>
<td>0.956</td>
</tr>
</tbody>
</table>

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### Real time monitoring

![Real time monitoring image](image)
Repeat probe position

Arm bridge system (ABS)

Free breathing monitoring
Liver
Active breath hold monitoring
Pancreas

US Challenge 102

Can the probe be placed in a repeatable way?

Liver  Prostate

Liver  Pancreas

US challenge 102

When the US probe is placed on the patient, the target organ deforms

For accurate radiation treatment, same soft tissue deformations should be created between Simulation and Treatment
Active robotic arm

- Less user dependent: can record the position and force of the probe and repeat probe placement
- Feedback: can fine adjust the position and force based on the acquired US image
- Complex docking: docking system needs to be designed for quick clinical setup

Experiment

Goal:
1. To place the target organ to the simulation day position
2. To create the same soft tissue deformation between sessions

Experiments:
- 3 metal markers are implanted into a canine kidney to represent a tumor
- Implanted markers are localized in the US and CT images taken in the experiment
- Marker positions in the CT images are used as the ground truth
**Experiment**

### Claim:
- The soft virtual fixture helps to create the same soft tissue deformation

**For each interfraction day:**
- Marker position differences between Hard VF and Reference US images & Soft VF and Reference US images are compared

**Reference**

**Hard VF**

**Soft VF**

- Compared to the alignment to using CBCT of spine only:
  - With the US image feedback, the setup accuracy is improved by 42%.
  - With the soft virtual fixture algorithm, it is improved by 61%.
Summary

Passive arm (arm bridge system)
+ Small size
+ Easy docking
- User dependent

Active robotic arm (URS)
+ Less user dependent
+ Feedback loop
- Complex docking

Questions