Clinical Practices of Managing Implanted Medical Devices for Proton Therapy

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Disclosure

An employee of the City of Hope at Irvine, CA

No relevant conflict of interest in this presentation
Learning Objectives

• To be familiar with objects implanted in the human body
• To be familiar with how proton treatment planning (TP) handles the objects
• To be familiar with the adverse effects if the objects are not handled well for proton TP
What can be inside a human body?

- Clips
- CIEDs
- Markers
- Dental
- Breast
- Spine
- Hip
- Bone
Device Materials

Metal implants

• Usually, the metals in a human body can be:
  ➢ Titanium-Chrome-Cobalt (surgical clips, spine support)
  ➢ Stainless Steel (breast expander, orthopedic surgery)
  ➢ Silver (dental filling)
  ➢ Gold (marker, dental filling)
Why is it a big deal in Proton RT?

- **Sharp distal dose falloff – Double-edged sword**
  - A proton beam is much more sensitive to changes in the beam path than a photon beam -> range variations
  - The range variations eventually transfer to dose errors
  - Instead of resulting in a reduced dose, the target may be missed or the spared organs at the distal end may be flooded
**HU-SPR (Stopping Power Ratio) Curves**

Fitted lines through the HU vs. SPR data using 3 different categories

<table>
<thead>
<tr>
<th>HU</th>
<th>SPR</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>-1000</td>
<td>0.000</td>
<td>Theoretical point</td>
</tr>
<tr>
<td>-200</td>
<td>0.797</td>
<td>Tissue-like</td>
</tr>
<tr>
<td>-120</td>
<td>0.943</td>
<td>Adipose-like</td>
</tr>
<tr>
<td>-20</td>
<td>1.011</td>
<td>Adipose-like</td>
</tr>
<tr>
<td>35</td>
<td>1.034</td>
<td>Tissue-like</td>
</tr>
<tr>
<td>100</td>
<td>1.100</td>
<td>Tissue-like</td>
</tr>
<tr>
<td>160</td>
<td>1.107</td>
<td>Bone-like</td>
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<tr>
<td>1500</td>
<td>1.751</td>
<td>Bone-like</td>
</tr>
<tr>
<td>3300</td>
<td>2.616</td>
<td>Bone-like, theoretical point</td>
</tr>
</tbody>
</table>

HU Range | Category
---------|---------|
-1000 to -200 | Tissue
-120 to -20 | Adipose
35 to 100     | Tissue
160 and above | Bone
Clinical Considerations

Metal implants

• Using a 16-bit scan can reveal more information about the implant, including ingredients and actual dimensions

• Physicists determine if overwrite HU and how to overwrite HU for metal cases

• Make sure metal HU (up to gold) is in SPR-HU curve

• More like a case-by-case scenario than one solution fits all

• Generally, we try to avoid shooting through metal

• During planning, the robustness settings should consider the metal material and size

• For Monte Carlo calculation, the material table is limited for metals

• Create a template for frequent metal implants
Dual Energy CT Acquisition

- Dual Layer
- Fast kVp switching
- Split-filter (Siemens Twin Beam)
- Rotate-Rotate
- Dual Source

Low energy
High energy
Dual Energy CT Advantages

- $\text{Rho}_e$ and $\text{Z}_{\text{eff}}$ image
- Get SPR directly
- Less uncertainty
- Contrast removal
- Virtual monoenergetic images
- Better target and OAR delineation
Clinical Case: Mandible Plate
Clinical Case: Breast

Cumulative Dose Reconstruction Using CBCT-Based Synthetic CT for Interfractional Tissue Expander Metallic Port Variability

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Clinical Case: Spine
New materials might reduce the effect
Testing Phantom
Comparison of CTV 50 Gy
CTV 50 Gy Uncertainties
Spinal Cord Max Dose Uncertainties
Comparison with Photon RT-CTV 50 Gy
Comparison with Photon RT- Spinal Cord
Comparison of Dose Accuracy: AAA, Acuros XB, MC²
Clinical Case: Hip Replacement
LVAD - Left Ventricular Assist Device
LVAD Experiments
LVAD Results

Figure 2. The LVAD's motor power, average flow, and motor speed during continuous irradiation of the pump. Note that the values on the y axis on the left side of the figure refer to the motor power (watts) and average flow (liters per minute), while the values on y axis on the right side of the figure refer to the motor speed (revolutions per minute). LVAD, left ventricular assist devices.
Discussions

• Limited beams angles limit the target

• Multibeam angles might reduce the uncertainties, but increase the treatment time

• Larger dose uncertainties exist if not considered well

• Daily treatment shifts of the objects will cause clinical challenges-multi plans or adaptive plans are needed

• Building up a clinical database for common devices is very helpful
Summary

- Management of Implanted Devices is important in Proton RT
- For known devices, needs to assign correct HUs corresponding to RSP
- For unknown devices, try not to direct shoot it and assign relative larger uncertainty if needed
- Use Monte Carlo algorithms to double-check the dose accuracy
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