Design and performance of an MR-compatible water calorimeter

M. D’Souza\textsuperscript{a,*}, H. Nusrat\textsuperscript{a}, J. Renaud\textsuperscript{b}, G. Peterson\textsuperscript{c}, N. Entezari\textsuperscript{a}, A. Sarfehnia\textsuperscript{a,c}

\textsuperscript{a} Ryerson, Department of Physics, Toronto, Canada  
\textsuperscript{b} National Research Council, Canada, Ottawa, Canada  
\textsuperscript{c} University of Toronto, Department of Radiation Oncology, Toronto, Canada
What is water calorimetry

• Method for obtaining absolute dose to water
• The radiation induced milli-kelvin temperature rise is measured
• Absolute dose at a point can then be determined

\[ D = C_{w,p} \cdot \Delta T \cdot \prod k_i \]
MR-linac

- Elekta Unity
  - 7 MV beam
  - 1.5 T MRI

- Provides real time imaging during treatment

- Different Dosimetric impact
  - Due to the Lorentz force
  - Particularly pronounced around air cavities
Goals

- Optimize and construct an MR-compatible water calorimeter
- Measure absorbed dose in the presence of a magnetic field
Optimization of calorimeter

- FEM analysis (COMSOL Multiphysics) was used to simulate heat transfer within calorimeter
- Simulations looked at
  - Calorimeter design
  - Materials used
  - Sensitivity to thermal variations
Optimization of calorimeter design
Optimization of insulation materials
Optimization of glass vessel

- Point of measurement contained inside glass vessel
- FEM analysis was used to optimize $k_{ht}$
- Parameters varied included
  - Top glass thickness
  - Bottom glass thickness
  - Vessel height
- Thermistor position inside vessel was also studied

Final design
Imaging
• Calorimeter placed under an Elekta Versa 6FFF beam
• Measurements (n=30) yielded a 0.06% standard error
• Dose measured agreed with NRC calibrated ion chamber to within 0.3%
Performance in MR-linac

- Calorimeter was loaded on railing of couch
  - No external modifications needed
- Electronics placed between RF door and linac door
- In presence of magnetic field
  - Standard error: 0.19%
  - Agreed with NRC calibrated ion chamber to within 1.5%
Summary of results
Conclusions

• A portable MR-compatible water calorimeter was successfully built
• It can be positioned using imaging (KV, CBCT, MR)
• Successfully measured absorbed dose in Elekta Versa and Elekta Unity
## Acknowledgements

**Sunnybrook**  
Arman Sarfehnia  
Viktor Iakovenko  
Phillip Au  
Gerrard Peterson  
Harry Easton

**Ryerson**  
Humza Nusrat  
Niloufar Entezari  
Carl Kumaradas  
James Grafe

**NRC**  
James Renaud  
Malcom McEwen  
David Marchington