The need for standardization of dosimetry in experimental radiation biology

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Motivation

- Radiobiology:
  - Dose vs. Effect
- Requires:
  - Accurate dose
  - Comprehensive dosimetry reporting
- There are concerns that requirements are not being met

Figure 1: Dose-survival curve for control and with administration of Rutin.\textsuperscript{1}

\textsuperscript{1}Patil SL, Somashekarappa H M, Rajashekar K P. Radiomodulatory role of Rutin and Quercetin in Swiss Albino mice exposed to the whole body gamma radiation. Indian J Nucl Med 2012;27:237-42
Motivation

- 28 radiobiology papers were selected
- Dosimetry reporting was reviewed
- Results compared with the recommendations from the 2011 NCI, NIAID, NIST workshop\(^2\)

## Motivation

<table>
<thead>
<tr>
<th>Category</th>
<th>Information</th>
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<td><strong>Absolute Dosimetry/Calibration</strong></td>
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Table 1: Percentage of papers compliant with recommended standards for dosimetry reporting.
Irradiator Spot-Checks

- **Spot Checks**
  - Test of dose accuracy of irradiators

- **12 checks performed**
  - Irradiators located in the US and Japan
  - Radionuclide and x-ray irradiators

- **Dose refers to absorbed dose to water**

Figure 2: Kimtron, Inc. cabinet x-ray Irradiator at UWADCL
Figure 3: PMMA Mouse phantoms
Diameter=13.5mm
Length=65mm
Methods and Materials

- **TLDs**
  - Harshaw LiF:MgTi TLD-100 1mm³ microcubes
  - TLDs were handled using the Cameron Method and read using a Harshaw 5500 TLD reader
    - 400°C 1 hour anneal
    - 80°C 24 hour anneal
    - Stored 24 hours between irradiation and readout
  - TLD raw data was corrected for control and relative response

Figure 4: TLD microcubes (courtesy of Samantha Simiele)
Methods and Materials

- **Spot Checks**

Figure 5: Customer irradiation process
Methods and Materials

- **Calibration Irradiation**
  - Two calibration mouse phantoms are irradiated
    - 1 Gy
    - 4 Gy
  - Irradiation is carried out with NIST-traceable beam quality using Advanced X-Ray CP320 x-ray at UWADCL
    - 1 m from source
    - 10x10 field
    - TLDs center of field

Figure 6: Calibration irradiation setup
Methods and Materials

- Air Kerma to Dose Conversion
  - Work by Tina Pike, PhD
  - Monte Carlo calculated conversion factor
  - Calculated for each standard beam quality

\[ N_K = \frac{K_{air}}{(D_{chamber} \cdot M_{air})/\left(\frac{\bar{W}}{e}\right)} \]

3Pike, T. Leah. (2012) A dosimetric characterization of an electronic brachytherapy source in terms of absorbed dose to water. [Madison, Wis.: University of Wisconsin-Madison].
Methods and Materials

- Uncertainty in ADW
  - TLD and irradiation: 1.7%
  - Air kerma calibration: 0.45%
  - Dose calculation: 1.7%

- Quadratic sum
  - 2.4%

- Total combined relative uncertainty at $k=2$
  - 4.8%
Radionuclide Irradiator Results

![Bar graph showing percent deviation by facility]

- **Facility 1**, **Facility 2**, and **Facility 3** have similar percent deviations, each around 2%.
- **Facility 4** has a slightly higher percent deviation at around 4%.
- **Facility 5**, **Facility 6**, and **Facility 7** show a significant increase in percent deviation, with **Facility 7** having the highest at around 12%. 
X-ray Irradiator Results

![Bar Chart]

- Percent Deviation vs Facility
- Facilities 1 to 5
- Facility 5 has the highest deviation
- Facilities 1 and 2 have the lowest deviation
Conclusions

- Dosimetry reporting in radiobiology articles does not meet the recommended standards
- Many facilities failed to deliver an accurate dose in a simple, well-defined geometry
- Dose accuracy more of a concern with x-ray irradiators
  - X-ray irradiator use expanding
  - Radionuclide irradiators being phased out
Future Work

- Expand the mouse phantom spot check program
  - Test more facilities
  - Allow for follow-up tests
- Reduce the uncertainty in the dose calculation
  - Characterize the UWADCL irradiator
  - Develop Monte Carlo model of irradiator
  - Adjust energy and filtration of calibration beam to match irradiator
  - Perform spot-check of irradiator
  - Apply this method to other sites to closely match beam quality
Thanks

- UWADCL customers for their continued support
- Kimtron, Inc. for their information and assistance
- Keith Kunugi and Cliff Hammer for their work with the mouse phantoms
- Tina Pike, PhD for her Monte Carlo simulations
- Ben Palmer for his assistance with equipment and experimental setup
- Professor Larry DeWerd, Professor Wes Culberson, Samantha Simiele and Michael Lawless for their guidance
- The students and staff of the UWMRRC for their assistance
References

- Pike, T. Leah. (2012) A dosimetric characterization of an electronic brachytherapy source in terms of absorbed dose to water. [Madison, Wis.: University of Wisconsin-Madison].