Improving kV irradiation protocols for cell cultures with a full dosimetric evaluation including culture preparation variability and vessel-specific factors

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THE PROBLEM

Deficiencies in dosimetric evaluations for cell irradiations can lead to inherent dose errors.

Factors of concern include:

- Irradiator end-effect (ramp-up dose)
- Beam timer end-effect (parameter rounding)
- Vessel-specific scatter factors
- Culture medium preparation variability
- Well-to-well differences in multi-well plates

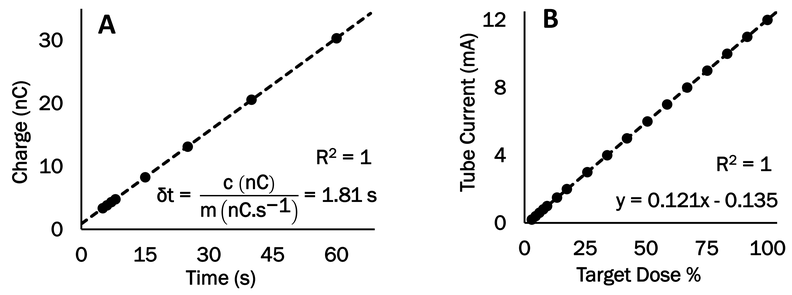
OBJECTIVES

To increase dose reporting accuracy and reproducibility in cell irradiations by:

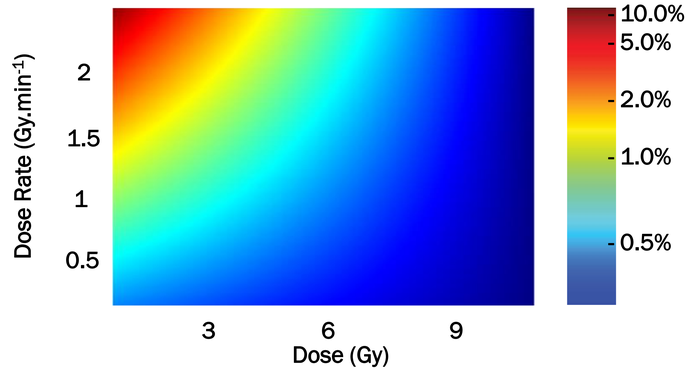
- Expanding our kV irradiator characterization
- Performing film dosimetry to measuring differences in scattered dose for different culture preparations

IRRADIATOR CHARACTERIZATION

- The flatness (-5% x-axis, +5% y-axis) and symmetry (<1%) of the beam at 80% field width were confirmed with Gafchromic™ EBT3 film.
- The in-air dose rate of the 320 kVp, 2 mm Al beam (HVL = 1 mm Cu) beam on our X-RAD 320 irradiator was determined per TG-61.
- Irradiator end-effect (δt) of 1.81 s was extrapolated from a linear plot of beam time versus charge collected in an ion chamber.

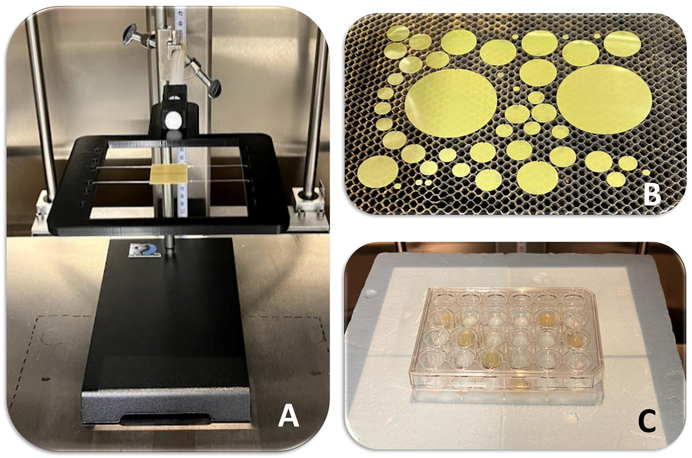


(A) Irradiation time versus charge.
(B) Tube current as a function of dose proportion against TG-61 dose rate.



End-effect-induced dose error as a function of the prescribed dose and beam current

CELL PLATE DOSIMETRY



(A) Film segment suspended "in-air' using 3D printed paddle.
(B) Laser-cut film discs.
(C) Cell IR dosimetry setup

Scan of laser-cut film discs for 24-well plate.

Vessel		Medium Preparation Factor		Well position Factor		Total Contributions	
Type	Factor	-0.5 mm	+0.5 mm	Outer	Inner	Min	Max
85 mm	1	1.004	0.996	-	-	-0.4%	0.4%
35 mm	0.988	1.012	0.988	-	-	**-2.4%**	0%
6-well	1.033	**0.988**	**1.012**	0.992	1.008	1.3%	5.3%
24-well	1.033	**0.988**	**1.012**	0.989	1.011	1.0%	**5.6%**

Scatter factor contribution table

- Cell plate dose profiles were flat (<2%) and symmetrical (<4%).
- Increasing medium depth decreased the dose in multi-well plates by 2.4%/mm – it is estimated that scattered dose increases may be overwhelming dose absorbed with depth over the first 4 mm to increase the total dose in higher volume preparations.
- Centrally located wells received ~2% more dose than wells at the plate circumference
- Scatter factors consistent at second beam quality: 320 kVp, 2 mm Al beam (HVL = 3.6 mm Cu)

CONCLUSIONS

Dose error due to beam time rounding is overcome by "mA tweaking" using the dose vs current relationship

End-effect-induced dose error scales with dose rate, becoming significant for high dose rate, low dose irradiations – ***7% for a 1 Gy irradiation*** *at 12 mA.*

Preparation variabilities may cause dose discrepancies of ***8% or more*** between different cell culture plates, growth medium volumes, and well positions.

Cell culture irradiations should employ:

- vessel-specific output factors in dose calculations
- strict culture medium volume targets
- avoid equating inner and outer well doses

ACKNOWLEDGEMENTS

The CO_2 laser cutters used for this study are located at a local open workshop facility in Baltimore city:

OpenWorks, 1400 Greenmount Ave, Baltimore, MD 21202
www.openworksbmore.org

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