UBC PHAS Med Phys Comprehensive Exam –

Sample Question

During your morning commute, you are contemplating an upcoming clinical trial comparing a new VMAT technique using 6 MV x-rays for prostate SABR (stereotactic ablative radiotherapy) against a conventional 6MV technique. The study hypothesis is that anterior surface dose for VMAT SABR is different than for conventional treatment and you need to do patient specific dose monitoring using optically stimulated luminescence dosimeters (OSLDs) on the first 10 patients treated, 5 in each study arm.

a) (20%) Describe (with the aid of a diagram) the basic physics behind the Optically Stimulated Luminescence (OSL) process.

b) (20%) In the context of OSL detectors, briefly define or explain:

i) Recombination centre

ii) Storage trap

iii) Activation energy

iv) Annealing process

v) Effective atomic number

c) (20%) The trial protocol calls for OSLDs to be placed on the anterior surface of the patient's abdomen, on the central axis of the beam when the gantry is vertical and pointing down, with the patient in the supine position. The SABR technique is designed to target just the prostate and spare surrounding healthy tissue and sensitive organs.

i)) Draw a schematic of the patient indicating where you would place the OSLDs, and the relevant patient anatomy in the transverse and sagittal planes, including four key internal organ structures.

ii) Using your knowledge about the characteristics of a 6 MV photon beam, how would you relate the dose measured with the OSLDs to the dose received by the prostate for the conventional plans that use an anterior-posterior parallel opposed set of beams?

Potential flavour 1 for sections d) and e)

d) (20%) You realize you first need to calibrate the OSLDs before embarking on this study. Using a single batch of OSLDs, your plan is to deliver 100 to 500 cGy under standard reference conditions to 6 OSLDs and record the raw OSL reading for each. You will then fit a linear model to the measurements to use as a calibration curve.

Dose = m x + b ,

Where x describes the OSLD reading.

How can you find out how reliable this fit is and what the estimated uncertainty in your measured doses will be when you apply it in your study?

e) (20%) After 5 patients in each arm have completed their treatment, you analyze their OSLD data and find the following:

Arm 1 – OSLD measured dose for 5 patients receiving parallel opposed beams:

2.2 Gy, 2.3 Gy, 3.1Gy, 3.6Gy, 4.6 Gy

Arm 2 OSLD measured dose for 5 patients receiving VMAT:

1.7 Gy, 1.8 Gy, 2.7 Gy, 3.3 Gy, 4.2 Gy

Calculate the standard error of the mean for each group.

You run an unpaired t-test (two tailed) and find the following: P =0.5338

The 95% confidence interval on the difference in the means (-2.1 Gy to 1.8 Gy)

State the null hypothesis for this experiment and how do you interpret the obtained p-value.

Define and interpret the 95% confidence interval for this experiment.

Another flavour for d) and e)

Your plan is to take clinical dose measurements using OSLs, but you first need to calibrate them. Using a single batch of OSLs, your plan is to deliver 5, 10, 25, 50, 100, and 200 cGy and record the raw OSL reading for each under standard reference conditions. You will then fit a model to the measurements to use as a calibration curve.

d) (20%) Assume you will fit a generic model *f*(*x*; *a, b*) where *x* is the raw OSL reading, *f* has units of Gy, and both *a* and *b* are model parameters that will be fit. Explain how *f*(*x*; *a, b*) can be fit to the data, and derive the (ordinary) least-squares solution. (Hints: there are two equations that determine parameters *a* and *b*).

e) (20%) If you take the OSL dose-response to be linear, so that $f(x; a, b) = a + bx$, show the optimal a and b are

$$b = \frac{N(\sum_i D_i\, x_i) - (\sum_i D_i)(\sum_i x_i)}{N(\sum_i x_i^2) - (\sum_i x_i)^2}$$

and

$$a = \frac{(\sum_i D_i) - b(\sum_i x_i)}{N}$$